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ENGINEERING PERFORMANCES.

BY COMMANDER J. W. REEVES, JR., U. S. NAVY, MEMBER.

Engineering Performances, or Steaming Contests as they were called in 1909, owe their beginning to the Gunnery or Target Practice Competition which had begun some years earlier and which had produced very beneficial results.

In July, 1897, the old target practice regulations, which had been in effect for many years, were superseded by a new set. The latter practically doubled the frequency of the regular practices, made them simpler and less irksome and systematized and increased the facilities for preliminary training. The monitor *Amphitrite* was designated as a gunnery training ship. Men from the fleet were sent to her for a course of training which included development of training facilities and methods, training of personnel—particularly gun captains and pointers—and the firing of test practices.

These training measures were temporarily interrupted by the Spanish-American War but were taken up again with renewed energy at its close. At first these matters were carried on almost entirely by the forces afloat. But in 1902 the Bureau of Navigation detailed an officer to take charge of and coordinate under the Bureau everything relating to improvement in gunnery. Necessary funds were obtained from Congress and prizes were offered for excellence in gunnery. The qualifications for gun captains and gun pointers were established and extra compensation provided for those qualifying. New methods and facilities for training were developed. A progressive advance was made in the nature of practices required and of the standards by which the results were measured. The results were tabulated and made available for study and analysis. In 1907 the annual report of the Chief of the Bureau of Navigation stated "The present system of training the gunnery personnel has been continuously successful since it was adopted in 1903. The records of gunpointers for this year show that both the rapidity of fire and the percentage of hits are greater than in any preceding year though the conditions governing the tests of gunpointers and gun crews were more difficult than heretofore."

When the Atlantic Fleet started around the world in December, 1907, it became immediately apparent not only that there were marked differences in the fuel expenditures of similar ships with similar machinery, but that the greater expenditures of uneconomical ships would materially increase the fuel bill and the difficulties of replenishing the fuel supply. When the fleet reached Rio Janeiro the Commander-in-Chief published an order establishing a system of competition in steaming and in machinery efficiency. It sought to determine accurately the results attained and to make them available to all concerned as an incentive to increased efficiency in steaming and increased reliability in the operation of machinery.

These measures resulted in a saving of 1460 tons of coal between Rio and Magdalena Bay over what would have been consumed at the rate in effect before the order was issued. They resulted in fewer derangements and more prompt and effective handling of those that did occur. They contributed in no small degree to the

success of a cruise which was properly regarded as an engineering feat. The Chief of the Bureau of Navigation characterized this order as one of the most important and far-reaching that had been issued since the creation of the gunnery system previously referred to.

On the return of the fleet to home waters, steps were taken to extend this system to the entire navy in a manner similar to that followed with gunnery exercises. General Order No. 26, of June 4th, 1909, carrying this into effect began as follows: "In view of the fact that the efficiency of any vessel in battle is based to a very large extent upon the performance of her engines and appurtenances and that her value as a strategical unit is directly dependent upon the economical use of such amount of coal, oil and other similar supplies as it is possible for her to carry, the Department has determined to establish yearly competitive steaming contests between battleships, armored cruisers, torpedo boat destroyers and torpedo boats." The standards of comparison were to be based on past performance. Money prizes and other rewards were established in the manner that had been followed with gunnery competition. So much for the beginnings of the steaming contests.

With the exception of a period during the World War the steaming contests or engineering performances have been continued to date. Of the benefit which has resulted it is impossible to make any accurate estimate. It is very easy to determine the change in performance from one year to another. But to determine how much of this change is due to a change in efficiency and reliability of operation and how much to other things, such as the conditions and requirements of operation, is an entirely different matter. Furthermore it is pure guess as to what the results would have been had there been no compilation of data and no scrutiny and comparison of results. There can be no doubt, however, that the result has been very definitely in the direction of greater economy and reliability.

That engineering performances have not been an unmixed blessing cannot be denied. The rules under which the competition functioned showed a steady tendency toward expansion and complication. Beginning with nine pages of typewritten instruction in 1909, the rules increased to over two hundred pages of printed

matter plus seven so-called confidential supplements. The amount of time and study necessary to become familiar with these rules was no small item. Their complications and intricacies served to suggest and foster evasions. In general, their trend was to make competition an end in itself instead of a means to an end.

The amount of data taking and recording, and the computations and clerical work required by the competition was a burden of no small proportions. In 1910 seven forms had to be filled out daily and this, according to the statement of the engineer officer of one of the armored cruisers, required an average of two hours a day in port and three and a-half hours per day underway. Some changes in these requirements were made from time to time but with no material reduction in the time and labor involved. In 1929 the commander of a destroyer squadron expressed the opinion that the paper work necessitated by the competition would in time result in a marked decline in the material condition of destroyer engineering plants. Computations required for purposes of competition alone absorbed the time which should have been spent in supervising the operation of machinery and the making of repairs. In 1931 the majority of the administrative commanders afloat were of the opinion that one of the most serious objections to the competition was the excessive amount of time and labor required to collect and compute data, and to write up and check Form H.

An ever increasing amount of emphasis was placed on competitive features as opposed to the mere requirements of good and efficient engineering. The increase in special rules and the adoption of all sorts of special allowances were intended to equalize all kinds of machinery plants and all sorts of conditions. This not only failed of accomplishment but it tended to set up a series of false operating values and conditions directly opposed to the principles for which the competition had been established.

As a result of these conditions and the increasing tide of service disapproval, the Secretary of the Navy, on August 1st, 1931, convened a Board to Devise an Engineering Competition which should, if possible, retain the advantages and eliminate the objectionable features of the competition then in effect. The board was composed of Rear Admiral O. G. Murfin, U. S. N., as Senior Member, a representative from the fleet, one from the office of Fleet Training and one from the Bureau of Engineering.

Before the board met a canvas was made of the administrative commanders afloat and the officers on duty in the Department to obtain their opinions as to objections to the existing competition and recommendations as to changes. A study was made of the recommendations of recent Fleet Maintenance Boards and of the annual reports of commanders afloat insofar as they related to the competition. In short, the board was as thoroughly informed of authoritative service opinion as it was possible to be. In general, service opinion was largely in agreement with the opinion of the 1931 Fleet Maintenance Board the main outlines of which were as follows:

(a) The principles of the existing competition were correct.
(b) The rules for carrying it out were unsatisfactory but satisfactory rules could be devised.
(c) They should be such as to require a minimum of record keeping.
(d) They should consist of trials to demonstrate ability to meet design characteristics such as speed, and of daily fuel expenditure records such as to permit analysis of performance and to promote economy and reliability of operation.
(e) Reliability should be indicated by freedom from derangements, penalties for which should be assigned by type commanders.

After a study of two months the proposals of the board in the form of a preliminary report were sent to the forces afloat for comment and recommendation. After a further study of the matter in the light of these comments, which were generally favorable, the recommendations were approved by the Secretary of the Navy and placed in effect on July 1, 1932.

A thorough understanding of the rules requires a study of their provisions and of the deliberations preliminary to their adoption. For those who have had no opportunity or occasion for such a study, a discussion of some of the more important or controversial rules will lead to a clearer understanding of how they operate and why.

Previously all vessels of the same type were compared with one another regardless of the fact that they were operating in widely different localities and under widely different conditions of service. Because conditions differed, results also differed. To place results on a basis of comparison it was necessary either to make the conditions the same or to attempt to evaluate the differences. The latter alternative was tried in the early period of the competition. It resulted in a complication of special rules and special allowances but did not accomplish the purpose intended. The idea of the new rules is to make the comparison between the members of groups, all vessels in the group being of the same type and operating together. Thus, instead of placing all cruisers in competition together they are divided into two groups:—those with the Scouting Force, and those with the Battle Force. The destroyers are divided into three groups:—those in the Scouting Force, those in the Battle Force, and those in the Asiatic. The comparison is between vessels in the same group. They operate together, under the same commander, in the same localities, meeting similar requirements of duty. In such groups and over a year's time the conditions of operation will equalize themselves as nearly as it is possible to do so.

The adoption of the group system made possible another important change; viz., the transfer of all administrative control of competitive matters from the Department to the group commander. The group or administrative commander is responsible for the reliability of his ships. It is logical, therefore, that he should receive the reports of machinery derangements required by the rules, and that he should decide how serious they are, what should be done to prevent their recurrence and to what extent they should reflect on the ship concerned. Quite aside from the competition one of the most important of an administrative commander's duties is to determine whether his ships are dependable and reliable and, if not, to take steps to make them so.

An equally important duty of an administrative commander is to determine whether his ships are able to meet requirements as to speed, fuel economy and ability to steam smokelessly. To perform this duty intelligently it is imperative that he receive the trial reports and performance reports. They furnish him not only with

an indication of how good performance has been but also with a means of analyzing it to determine where and in what way improvement is needed. Thus the engineering reports furnish the administrative commander with data for a determination by means relatively exact, as compared with information available to him about other activities, of what his ships have done in engineering. He should evaluate these results in the light of existing circumstances and thus appraise the work of his subordinates. This appears to be definitely a part of his administrative duty.

Vessels which operate by themselves or in numbers too small to warrant forming a group have been placed in individual competition. Their current performance is compared with their previous performance. Among these vessels the differences in the localities in which they operate, and in the duties which they are required to perform are especially marked. Therefore, it is no more correct to compare two vessels of the same type in individual competition than it would be to compare two vessels of the same type in group competition but in different groups. An analysis of the performance of a vessel in individual competition will indicate the trend of her performance whether upward or downward. And if the trend is definitely upward and the performance an outstanding one such vessel will receive its due recognition.

Such vessels as tenders and repair ships compete only in respect to the reliability factor; not in respect to the performance factor—fuel economy. The mission of these vessels is service to other vessels and it is most important that they should be able to render the utmost in service unrestricted by any over emphasized consideration of fuel expenditure. Furthermore the requirements of service are variables which cannot be accurately evaluated and for which, therefore, standards cannot be set.

The performance factor relates to fuel economy and is the comparison of the fuel expended with the standard fuel allowance. The data required by this factor is the minimum required for the ship's record—the engineering log—and for the proper supervision of any engineering plant. This consists simply of the readings of revolution counter and fuel meter at the time of getting underway or anchoring and each hour, on the hour, thereafter. When the

speed is materially changed during any hour the fuel expenditure for that hour does not bear its normal relation to the average revolutions per minute for that hour. It is considerably increased. There is no remedy for this condition except to increase the periods into which the hour is divided and hence the number of readings of the counter, so that the effect is that of a recording power meter. However, this procedure involves a prohibitive amount of labor in collecting, recording and computing data. It has no great value from an engineering standpoint and directly opposes the purpose for which the competition was established. Computation on an hourly basis, when taken over a period of a year and for vessels which operate together is sufficiently equitable for comparative purposes.

It has been asserted that competition tends to influence unduly the judgment of commanding officers in regard to such matters as choice of speed, the time of changing speed and smart ship handling. In the choice of speed or of the time to change speed consideration must be given to such matters as the task in hand, the distance to be traveled, the time available, fuel economy, the weather and the comfort of personnel. There is every reason why due consideration should also be given to favorable results in competition and to obtaining logistic data and training in operation at speeds where needed. In these, as in every other question, the commanding officer must give proper weight to all considerations and make his decision accordingly. How correctly he does this is a measure of his soundness of judgment, one of the most important qualifications for command. There is no possible way in which a commanding officer can escape the necessity of and the responsibility for this exercise of judgment. In the matter of ship handling good seamanship is so preponderantly the main consideration that little thought need be given to other things. It may be observed, however, that the principles of good seamanship may be just as readily and as disastrously violated by the use of too much power as by too little. It is safe to say that the greatest economy of fuel is attained by the expert ship handler who does not use power unnecessarily but who never hesitates to use all that the situation demands.

The method of determining fuel standards is based upon certain fundamental principles laid down by the Board to Devise an Engineering Competition.

(1) Each vessel's standard allowances shall be determined from its own actual fuel consumption during the three previous years.

(2) Where there are two or more vessels in a class having the same machinery installation (referring to cruisers and destroyers), a single allowance shall be determined based on the average consumption of all of them during the past three years.

(3) Curves of standard allowances shall be drawn through points obtained from actual performance data of the vessel concerned computed in accordance with definite rules—the same for all vessels.

(4) Standards shall never be lowered but shall be raised from year to year when, if ever, the performance for a year at one or more speed points is better than the previously established points.

It would appear logical that sister ships having the same hull, machinery and propellers should also have the same standards. However, the battleship machinery plant is so large and spread out, as compared with a destroyer for example which has about the same horsepower, that very considerable differences exist even among vessels built on the same designs. In addition there are actual differences in such items as boilers and auxiliaries. After careful analysis it has been found preferable, therefore, to compare each battleship's current performance with her own previous performance.

Among cruisers and destroyers some differences exist between sister ships. However, the results of trials show that these differences are very small as compared with the results of differences in such matters as upkeep and operation. Small vessels are generally less accurate in the taking and recording of data and there is, therefore, a greater percentage of erratic data. Investigation shows that individual consideration of these vessels would so greatly reduce the amount of data in each case and so increase the effect of

erratic data that the determination of past performance, and therefore of standards, would be quite unsatisfactory. Moreover, the number of vessels and the increase in labor resulting is a consideration. Sister ships of the cruiser and destroyer type have therefore been given the same standards.

The 1932-33 standards for battleships were determined by individual ship performance data during 1928-29, 1929-30, 1930-31. Time did not permit including data for 1931-32. From Form H for these years was abstracted every run of four or more consecutive hours in which the average hourly revolutions per minute did not vary by more than one knot. For every run there was entered on a data sheet the number of hours, the average revolutions per minute and the gallons of fuel used. The entries were made in the appropriate column, there being a separate one for each speed, as 5 to 5.99 knots, 6 to 6.99 knots, etc. The columns were totaled giving for each speed the total hours, the average revolutions per minute and the average gallons per hour. This combined the best performances for three years by exact mathematical methods, giving each run its proper weight by using in each entry total instead of average fuel expended.

The resultant average revolution-per-minute versus fuel expended were plotted on cross-section paper. The points were joined by *straight lines*. This was the performance curve covering three years and therefore representing average conditions of fouling of the bottom during that period. Data obtained by the Board of Inspection and Survey with the *Tennessee* indicated that the increase in fuel consumption on account of fouling was of the order of 1 per cent per month. As the docking interval of battleships during these three years averaged eight months, the mean time out of dock was four months. Therefore the performance curve was reduced by 4 per cent to obtain what is known as the clean bottom curve. This also is the explanation of fouling allowance which in accordance with present rules is 1 per cent for each month out of dock.

For vessels then in commission, performance data obtained from the three years 1928-29, 1929-30, and 1930-31, form what may be called the basic curve of standards or allowances. Performance data for the year 1931-32 was computed. Where these points fell

above the basic curve, no change in it was made. Where they fell below, they were combined with the corresponding points on the basic curve in proportion to the hours of operation represented in each case. Data for eight months of the current year 1932-33 have been compiled and the curve again corrected in the same manner. The resultant performance curve is reduced by 4 per cent and becomes the clean-bottom standard allowance curve for the year 1933-34.

Vessels which are newly commissioned or recommissioned may be given the standard of their class if, as in the case of certain cruisers, they are similar to vessels having an established standard. If not they are given for their first year a standard determined by their modernization trial or acceptance trial data. The second year their standard is a combination of trial data with a weight of two, and one year's performance data with a weight of one. The third year their standard is a combination of their trial data with a weight of one, and two years' performance data with a weight of two. The fourth year their standard is the combination of their three years' performance. This is their basic standard allowance which is corrected each year thereafter as previously outlined in the preceding paragraph. After a very few years of this procedure it may be expected that allowances will be so well standardized that further changes will be negligible.

A vessel's reliability is largely determined by her ability to meet certain trial requirements as to high speed and smokeless steaming, and by her freedom from machinery derangements. As trials are expensive in time and fuel the number of trials that can be held during a year and their duration is limited. As these few trials must be considered as an indication of ability to meet the requirements over a period of a year it is important that the standards be high and that the penalties for failure be severe. For obvious reasons a failure must be followed by a demonstration of ability to meet these essential requirements. However, that cannot change the fact that the performance on scheduled trial was a failure and penalties are in order.

Derangements are machinery failures in current operation from any cause, which adversely affect a vessel's efficiency, mobility or ability to carry out the duty or task in hand. In the past, derange-

ments were penalized in accordance with an invariable schedule set by the Department. This fixed the penalty in accordance with the length of time that the execution of a duty or task was interfered with. As this old rule took no account of the relative seriousness of the derangement or of the degree of blame involved it was a source of considerable dissatisfaction. In an effort to make the penalty system more flexible and more truly representative of reliability, its administration was delegated to the group commander by the new rules. He was authorized to remit penalties in whole or in part so that the penalty might fit the derangement. He was authorized to impose penalties as he saw fit for anything which in his opinion denoted lack of reliability. The only stipulation was that his actions should be uniform.

These changes have not produced the results that were hoped for. The trend has been either to allow penalties to stand as originally incurred or to remit them entirely. This added very little to the flexibility of the procedure or to the possibility of making the penalty fit the derangement. The authority to impose penalties was used relatively little. Therefore these changes have had a negligible effect in making the reliability score reflect more accurately the opinion of the group commander as to the relative reliability of the vessels under his command. A very considerable number of vessels received no penalties whatever and were therefore rated as perfect in reliability and exactly equal, one with another. Consequently, for these vessels the reliability factor has exercised no effect whatever in determining standings in competition and thereby a double emphasis has been thrown on fuel economy. This is not desirable and has in the past led to unhealthy methods of operation. Moreover the desire to obtain a remission of an incurred penalty has caused the stressing of this feature to the detriment of a thorough and unbiased investigation aimed solely at determining the cause of a derangement and preventing its recurrence.

That a vessel is unable to perform a required task or that she is prevented from doing so for a certain period of time is a question of fact. That a vessel has had a certain number of such occurrences over a period of a year can be made a matter of record, which is obviously a more accurate procedure than dependence on

memory or estimate. By means of a penalty system including a schedule of penalties such a record may be transformed into a reliability score. But for such a score to have any value or meaning it must be based upon penalties which are commensurate with the seriousness and the degree of blame involved in each derangement. This cannot be accomplished by an inflexible penalty schedule. It can only be done by an administration of the penalty system by the responsible administrative commander with full authority to determine each case on its merits.

In an activity or sport which exists solely for the sake of competition the variables or inequalities are eliminated or controlled by the rules to the end that results or facts may accurately measure merit or efficiency or excellence. Every phase of the activity is designed with this end in view. But naval engineering has a very different reason for existence. Its variables and inequalities cannot and should not be controlled so that its results or facts may be considered an invariable measure of excellence. And that they are not necessarily or always such a measure needs no argument. It is the function of "Engineering Performances" to determine accurately engineering results or facts. These results or facts have to do with economy in fuel expenditure, freedom from derangement, and performance on trial. It is the function of the Administrative Commander to use the results or facts not as in themselves a final figure of merit but as a means of arriving at such a figure which shall combine results attained with difficulties overcome.

If to some this conception appears inconsistent with the principle of competition it is because competition is regarded by them not as merely a means to an end but as an end in itself. Undoubtedly the spirit of competition serves to stimulate interest and is to that extent beneficial. But it seems a mistake to regard competition as the sole cause of the great improvement that has taken place in engineering since its establishment in 1907. The fact is that before that time there was little interest in engineering and no worthy standards of performance were brought to the attention of personnel and enforced. Had results been accurately determined, had high standards been required, and had due recog-

nition been accorded there is every reason to believe that the improvement would have come about without the competitive feature that has existed heretofore.

To sum up the discussion, the following pertinent comment by Rear Admiral A. J. Hepburn, U. S. Navy, may be quoted:

"With or without competition the worth of any military service depends upon the spirit animating its personnel to make that service the most perfect instrument for its purpose humanly attainable. This determines the quality of its morale. Morale may be stimulated by measures which, working through the natural competitive instinct of men, satisfy a proper professional pride of individuals and thereby elevate the morale of the whole; but, when the competitive principle is put first and foremost and individual self-interest becomes the animating spirit, true military character is debauched and service morale takes an inglorious trend."

THE NAVY'S FUEL OIL SPECIFICATION.

By Lieutenant James E. Hamilton, U. S. N., Member.

INTRODUCTION.

The development of the use and application of fuel oil for use as a naval boiler fuel progressed somewhat in advance of the development of specifications covering the fuel oil. Prior to 1910, fuel oil as required was purchased as "Texas fuel oil," "California fuel oil," simply as "fuel oil" or on specifications prepared locally by the purchasing activity.

When, in 1909, the Bureau of Supplies and Accounts concluded that purchase on annual contract for delivery at specific points in required quantities was desirable, it requested the Bureau of Steam Engineering to furnish a specification.

A specification was prepared and included as a part of the contract for purchase of fuel oil for the fiscal year 1911, the first annual contract for fuel oil for naval use. Until the latter part of the World War, the Navy Department held full control of its fuel oil specifications and this control was lodged almost entirely in the Bureau of Engineering. Each year the current specification was reviewed and such changes as experience indicated to be desirable were made by Supplies and Accounts on the recommendation of Engineering. The specification was not printed as a Navy Department specification in leaflet form but appeared only in schedules and contracts for the purchase of fuel oil.

During the war, it was found necessary to create a number of boards and committees for the purpose of coordinating various material supply questions. One of these, the "Committee on Standardization of Petroleum Specifications," was created by the President to act under the United States Fuel Administrator. The committee was composed of a chairman appointed by the Fuel Administrator and one member appointed by each of the Secretaries of War and the Navy, the Director General of the

Railroad Administration, the Chairman of the Shipping Board, and the Directors of the Bureau of Mines and of the Bureau of Standards. The committee was directed to prepare specifications which should be "binding upon and govern all departments, bureaus, agencies, and offices of the Government" to be in effect until six months after the termination of the war. The Navy protested against its inclusion but without avail.

The Navy Department was represented on the committee by its Engineer-in-Chief, Admiral R. S. Griffin, who named Commander N. H. Wright to act as his technical adviser. On 2 October, 1918, the Committee issued its first specification which was revised four times, the last revision becoming effective on 29 December, 1920.

The wartime committee was replaced by the Interdepartmental Committee on Standardization of Petroleum Specifications, which in turn was superseded on 10 October, 1921, by the Interdepartmental Petroleum Specification Committee. The Navy's representative on both of these committees was Commander H. A. Stuart, U. S. N. The latter committee issued Specifications for Petroleum Products as Technical Paper 305 of the U. S. Bureau of Mines in March, 1922.

The Interdepartmental Committee was ultimately absorbed by the Federal Specifications Board as a subcommittee. Under this committee Federal Specification number 2, "Specifications for Petroleum Products" was issued on 31 October, 1922. This specification has been twice revised in March, 1924, and October, 1927, and is under revision at the present time.

Upon the dissolution of the wartime committee, the specifications issued by other Federal boards ceased to be binding on the Navy for military materials. Therefore, on 1 June, 1921, the Navy Department issued its first fuel oil specification in printed leaflet form as Navy Department Specification 7–0–1. This specification agreed in all technical details with the latest revision of the wartime committee's specification.

The primary purpose of the present paper is to consider the genesis and development of the Navy Department Specification for fuel oil and to consider wherein this development has fulfilled or failed to fulfill its purpose of protecting the interests of the Navy.

GENESIS OF THE FUEL OIL SPECIFICATION.

It is an unfortunate fact, from the user's standpoint, that the conditions which surround the genesis of a particular material specification, usually exert their influence permanently. This point is very thoroughly demonstrated in the case of fuel oil.

When the Bureau of Steam Engineering began the preparation of the specification, requested by the Bureau of Supplies and Accounts, in 1909, fuel oil was, and had been for some years, on the market. Marketers of fuel oil and many users, principally railroads, were canvassed for opinions as to the requirements of a fuel oil specification.

The result of the canvass was a set of seven requirements which formed the basis of the specification on which fuel oil was purchased during the fiscal year 1911.

Before considering these requirements and the changes which each has experienced since that time, it will be helpful to consider, generally, the conditions which surrounded the fuel oil supply at the time the specification was prepared. These conditions will be considered under seven heads.

1. *Economic Definition of Fuel Oil:*

Fuel oil was the portion of the crude oil which remained on the refiners' hands after the removal of such naphthas (gasoline) burning oils (kerosenes and other illuminants) and lubricants as he could market. If the supply of crude was excessive, surplus crude was itself available as a fuel. In general, fuel oil was a refinery by-product.

2. *Physico-chemical Definition of Fuel Oil:*

Fuel oil was a mixture of hydrocarbons plus certain impurities and almost without change these compounds and impurities were chemically the same as a portion of those which existed in the natural state in the crude.

3. *General Refining Practice:*

Crude oil was run through stills wherein it was heated and the lighter, more volatile compounds were removed by distillation. The distillation was carried through to completion in case lubricants were desired or was discontinued with the removal of the

kerosene fraction if the particular plant did not want or was not equipped to produce lubricants. In the former case, one fraction—gas oil, intermediate between the illuminating oils and the lubricants, was distilled off through necessity. Gas oil was normally used for enriching of artificial gas manufactured for household use. Any of it which could not be sold for this purpose was available as a high-grade fuel oil.

In the second case, the residue which remained after removal of the light fractions was the fuel oil. There were only two conditions which governed the characteristics of this fuel. These were the characteristics of the original crude oil and the purely physical changes due to the removal of the lighter compounds.

Both of the above fuels, gas oil and residue, were, in general, clean or strainable oils composed of stable hydrocarbon compounds. The last feature is vital to the consideration of this paper. Nature is characterized by stability. Minerals which exist in their natural state are normally subject to very slow alterations. The refining methods did not affect the chemical nature of any of the crude oil components but merely separated them physically.

4. *Extent of the Use of Fuel Oil:*

Fuel oil was in general use on the Pacific coasts by railroads, steamships, and manufacturers. This demand was limited because of the industrial youth of the western part of the country and was met entirely by the products of the California oil fields. The burning equipment used was designed for use with this oil and was entirely satisfactory. The Navy had no oil burning vessels on the West coast except the *Cheyenne,* a monitor which had been converted from coal to oil for experimental purposes. The *Cheyenne* used commercial equipment and experienced no difficulty in using California fuel oil.

West of the Mississippi, the use of fuel oil was very limited except for railroads and factories in the immediate vicinity of the oil refineries. A few merchant ships, particularly oil tank vessels, were using oil as fuel. All of the Navy's latest destroyers were oil burning exclusively and the battleships were equipped for burning either coal or oil. The fuel oils were produced simi-

larly to those of California but since the crude oils were lighter, more fluid, and less impure than the western oils, the resultant fuel oils were superior in these respects to the California product. The use of fuel oil in the East was being extended as rapidly as the oil companies' sales activities could make converts from coal.

5. *General Method of Use:*

For all types of users, commercial and Naval, ashore and afloat, the storage and handling system was very simple. Storage tanks were located close to the boilers with direct piping. In practically all cases except naval vessels, the fuel oil pump suction was always under a positive head and except for naval vessels, all users of fuel oil used steam or air for atomization.

6. *General:*

The Navy, principally the Bureau of Steam Engineering had been experimenting, working toward the adoption of fuel oil for naval use for over fifteen years. From 1904 the specific hindrance to the adoption of fuel oil was the *fear that the supply of crude oil* would be exhausted in the near future. It was generally assumed that as long as crude oil was available, fuel oil would likewise be available and the *quantity* was the only consideration.

7. *Existing Specifications:*

Specifications, as they existed in 1910, were in every case prepared to restrict undesirable characteristics of *known* fuel oils and in most cases the specification was drawn to apply specifically to a particular kind of fuel oil from a particular source, through a particular production process.

SPECIFIED CHARACTERISTICS—U. S. NAVY.
FISCAL YEAR 1911.

It has been mentioned that the first Navy purchase specification for fuel oil contained seven detailed requirements. These are described below:

I. *General:*

The wording of the general descriptive requirement which was used for the 1911 purchases is as follows:

"Fuel oil shall be a petroleum oil of the best quality, free from grit, acid, fibrous, and other foreign matter likely to clog or injure the burners or valves."

Properly, the above requirement should be divided into four parts. The first phrase is a general description which serves no useful purpose other than to open the specification. All fuel oil which was marketed in this country was petroleum oil. In Scotland, some oil distilled from shale was available and this was the only oil excluded by the clause.

For a purchase specification to state "of best quality" is of no value. The quality must be assured by the restrictions of the detailed requirements.

Absence of grit was specified to insure freedom of the oil from sand grains and metallic oxides which, being harder than the materials of pumps, piping, and burners, would scratch or erode these parts. No qualitative limit nor method of determination was specified, thus reducing this requirement to a descriptive statement of little value to the specification.

Freedom from acid was required because of the corrosive action of acidulated liquids. Acidity may be present in the crude oil when produced and carried through into the fuel oil residue or it may be caused by the formation of acids by oxidation of free sulphur followed by dissolving of the sulphur dioxide so formed with water, during the refining process. As in the case of grit, there is no limit nor method of determination stated so a second requirement loses its specification value.

Fibrous or other foreign matter likely to clog any part of the system could hardly be present in any fuel oil except due to gross carelessness or malicious intent during the refining processing. The undesirability of such impurities is apparent but the requirement is of little value because of its too general character.

II. *Sulphur.*

The fuel oil was restricted to a sulphur content not to exceed three-fourths of one per cent. No method of determination was specified but presumably any recognized laboratory method of sulphur determination could be used. Of course, such freedom of choice of method opens the way to disagreement if the actual

content approaches the limit. A sulphur restriction was considered necessary because of the possibility of sulphuric acid formation in the gases of combustion with subsequent corrosion of boilers and structures. The figure, three-fourths of one per cent, was arbitrarily chosen as probably sufficiently small to protect the boilers and also as sufficiently high to include practically all marketed fuel oils at the time.

III. *Free Water and Sediment:*

One per cent by volume was the limit placed on free water and sediment which meant, at that time, that at least 99 per cent of the fuel oil purchased would burn. The sediment would include any of the grit or fibrous materials previously excluded but would not identify them as present. The test specified for water and sediment required that 50 cubic centimeters of the oil and 50 cubic centimeters of 68-degree Beaume gasoline be mixed in a graduated glass beaker which was then permitted to stand for six hours. On standing, the hydrocarbons which are soluble in gasoline would form a top layer above the insoluble water and sediment which could then be measured.

IV. *Flash Point:*

Flash point has long been recognized as the determinant of a petroleum oil's potential fire hazard in handling and storage. The flash point is that temperature at which sufficient vapors are given off to cause a minor explosion when brought into contact with a flame. Below the flash point temperature no fire hazard exists. Determination of the flash point varies considerably with different methods of test. If the oil is heated in a closed container, the flash point will be much lower than if the test is made with the oil surface open to the air. Between different methods of closed cup testing and of open cup testing the variations are not large. The Navy specified a flash point not lower than 200 degrees F. by the Abel or Pennsky-Marten closed cup method. One or the other of these two methods was in general use throughout the oil industry in the United States, hence their adoption. The figure, 200 degrees F., was entirely arbitrary but was considered to be high enough for safety under naval conditions. It also agreed with the specifications for fuel oil of the British Navy. Since

many crudes were not topped sufficiently to raise the flash point to 200 degrees F., this requirement was somewhat restrictive and excluded a fairly large percentage of marketed fuel oils.

V. *Specific Gravity:*

The gravity requirement was placed at not greater than 30 degrees Beaume at 60 degrees F. For many years the specific gravity of petroleum and its products was widely used for specifying grades. It has gradually come to be realized that the gravity is not a governing characteristic. For naval fuel oil it can, however, serve two purposes. Fuel oil which approaches water in specific gravity is difficult to separate from contaminating water by the usual gravitational methods. A five per cent differential should be sufficient to permit ready separation, hence a specific gravity as low as 0.95, if the expected contamination is from fresh water, and 0.97 or 0.98 if from sea water, should be sufficiently low. The second function of a gravity requirement is to insure greater fuel concentration. The differences in the calorific values of fuel oils per pound are not great but a lighter fuel oil will have a much lower thermal value than a heavier one per gallon. Since the volume of fuel oil storage on board naval vessels is limited, it is apparent that the heavier the fuel oil bunkered, the greater will be the steaming radius of the ship. This appears to have been the reason for specifying an upper Beaume limit—the equivalent of a lower specific gravity limit.

VI. *Viscosity, or Fluidity:*

It is, of course, essential that fuel oils be fluid. In 1910, the mere fact of fluidity was considered sufficient and no truly quantitative test of this characteristic was required. The test which was required is quoted in full:

"The oil shall flow freely and in a continuous stream through a ½-inch circular hole under a 2-foot head at a temperature of 40 degrees F. Oil that fails to flow freely and in the required quantities to pump suctions, pass through pumps, piping, and burners at a temperature of 40 degrees F. may be rejected."

The above clause was sufficiently general to safeguard the Navy if the latter part of it could have been enforced. A requirement that enough fuel oil for full power should pass through the system

at 40 degrees F. is very severe and could be met by very few oils today and probably would have been impossible to enforce twenty years ago.

VII. *Calorific Value:*

The fuel oil was required to have a calorific value of 144,000 Btu.'s per gallon. Provision was made for accepting oils with a calorific value as low as 135,000 Btu.'s per gallon at a reduction in price.

Since the heat value of the fuel was the thing which was being purchased, this requirement seemed quite proper at the time. It was not highly restrictive but in fairness should have included a bonus for thermal values in excess of 144,000 Btu.'s. To do so, however, would have placed a premium on the heavier oils which were inferior in other respects.

It is now intended to follow each of the above seven requirements through its history to the present time. Additional requirements which have been made will also be considered.

I. THE GENERAL REQUIREMENT.

The effect of inertia in specification writing is clearly shown by the present wording of the general requirement paragraph when it is compared with the original of twenty-two years ago. The two are given in parallel columns below:

Original	*Present*
Fuel oil shall be a *petroleum* (2) oil *of best quality* (3), free from grit, acid, *fibrous and* (4) other foreign matters likely to clog or injure the burners or valves.	*All* (1) fuel oil shall be a *hydrocarbon* (2) oil, free from grit, acid, *and fibrous or* other foreign matters likely to clog or injure the burners or valves. *If required, it shall be strained by being drawn through filters of wire gauze of 16 meshes to the inch. The clearance through the strainers shall be at least twice the area of the suction pipe, and the strainers shall be duplicate* (5).

The five changes which have been made are italicized and numbered above. They are separately discussed below:

(1). Addition of the word "all" before "fuel oil" first appeared in Navy Department Specification 7–0–1, dated 1 June, 1921. The files do not explain the reasons for the change and none can be surmised. The change does not appear to have any vital value.

(2). Substitution of "hydrocarbon" for "petroleum," first appeared in the specification for purchase for the fiscal year 1913. No record can be found of the reasons for the change but it seems probable that some one was looking ahead and foresaw the appearance on the market of fuel oils distilled from coal or shale. This change has never exerted any influence on the supply or quality of fuel oil. The appearance of substitutes is still a distant future event.

(3). The phrase "of best quality," previously mentioned as of no specification value, was retained until 1917 when it disappeared from the schedule covering purchases for the fiscal year 1918.

(4). Substitution of "and fibrous or" for "fibrous and" was a grammatical change made in the specifications for the fiscal year 1914 purchase. The reason for the change is apparent.

(5). The addition of an optional requirement that the oil be strained before delivery appeared in its present form in 1916 applying to the purchases for 1917. However, in 1913, coincident with (4) a similar condition was inserted under "Delivery requirements." The wording from 1913 to 1916 was: "On being discharged from tank vessels the oil shall be strained through filters of 16-mesh wire gauze, if required by the contracting officer."

The reason for the addition is quite easy to find. In 1912 one delivery of fuel oil to the Navy's tanks at Melville, R. I., was, by force of circumstances, delivered to destroyers for use almost immediately. No time for settling in the tanks was permitted and considerable difficulty was experienced by the ships. The trouble was traced and eventually attributed to clogging of strainers and burners with a consequent reduction of capacity. An investigation which followed showed that the same difficulty had been experienced on several other occasions.

The British Navy fuel oil specifications required straining of any delivery at the inspector's option. The Navy Department

submitted a proposed change making straining a requirement of the specification to the contractor who had supplied the dirty oil, for his comment. When he stated that he saw no objection, the additional clause was inserted, but as noted, on its first appearance it was applicable only to tanker deliveries.

II. SULPHUR.

The original sulphur limit of ¾ of one per cent was retained for three years. In 1913, on the recommendation of the Texas Company, it was specified that the test be made by the Graefe method which was the customary method in use by that company at the time.

In 1912, the Mexican fields came into prominence as a probable source of supply of fuel oil. In fact, it was considered that the only reasonably priced fuel on the Atlantic coast would come from Mexico in a very short time. This oil carried a very high, about 3 per cent, percentage of sulphur. The price consideration was urged on the Bureau of Steam Engineering as a reason for raising the sulphur limit. As a result of a study of the subject and a very comprehensive report submitted to the Engineer-in-Chief by Doctor Albert Sommer of Dresden, Germany, the sulphur limitation was entirely removed.

The study which had been made indicated that the only deleterious effect of sulphur was when it occurred in the form of sulphuric acid and that this was possible only when the gases of combustion cooled below the boiling point of water. As this condition did not exist on board ship, unlimited sulphur could safely be permitted.

In 1917, for the fiscal year 1918, sulphur again was limited to ¾ of one per cent. No reason can be found for the reversion. Apparently it met with some criticism for on 5 September, 1917, only two months after it became effective, the limit was raised to 1.5 per cent. This was one of the steps which was taken to broaden the supply field during the war.

The limit of 1.5 per cent held throughout the war and until Navy Department Specification 7–0–1 was specified for purchase. At this time the shift was made from "Fuel Oil (Navy Standard)" to Bunker "A" which is identical except for the absence of a

sulphur limit. During 1919 and 1920, a waiver of sulphur requirement for West coast deliveries was made, except that Navy yards were allowed to insist on low sulphur oil for use in metallurgical processes.

Since 1 January, 1921, fuel oil for naval vessels has been purchased with no restriction as to sulphur content.

III. FREE WATER AND SEDIMENT.

The original limit of 1 per cent was satisfactory and has been retained unchanged from the beginning. However, the original method of test had at least two unsatisfactory features and this test method has undergone several changes. The first of these features was the use of a special grade of gasoline, not available on board ship, as the solvent. This difficulty was overcome the following year (fiscal 1912) by permitting the use of kerosene, grade not specified, in lieu of gasoline if the latter was not on hand. For the grades of fuel oil which were on the market in 1912 it made little difference what the solvent was. The difference between the results with gasoline or kerosene is that with the former any so-called asphalt in the oil would be precipitated and show up as sediment. Fuel oils with large percentages of asphalt did not show up until the advent of the Mexican and Gulf coast of Texas fields. This was not recognized at the time, as the intended meaning of the word "sediment" was impurities such as inorganic minerals, and fibrous and gritty materials.

The second disadvantage of the original test was the length of time required. In probably all cases of fueling it was impracticable to wait for six hours while the sample was settling to ascertain whether or not the oil was acceptable. Complaints from the forces afloat brought this question to the attention of the Bureau and started a search for a shorter test method. The Texas Company suggested the use of a centrifuge and supplied an instrument for experimentation. A number of comparative tests of the settling and centrifuge methods of test were made at the Washington Navy Yard as a result of which the latter test was adopted and incorporated in the schedule for 1913. The centrifuge test is, of course, merely an accelerated gravity separation test. A solvent is used and only those constituents of the oil which are insoluble in

the solvent are separated. With the adoption of the centrifuge test, a reversion to gasoline as the solvent was made but the grade of gasoline was lowered to from 60 to 65 degrees Beaume which covered the motor fuels then in use. Except for a change in the solvent and closer dimensional specifications of the apparatus, the water and sediment test has remained unchanged since 1913.

In the meantime, recommendations had been received from the fleet that the water and sediment limit be reduced to ½ of one per cent. The refiners resisted the change on the ground that greater care would be required in handling the oil by the suppliers and that, therefore, an increased price would result. A compromise was reached by dividing the one per cent into not more than ½ of one per cent of free water and a similar limit for sediment. This limit was specified in 1912 but lasted for just the one year. In 1913, the limit was again 1 per cent combined.

In 1914 the present solvent, commercial benzol, was adopted and specified. In 1915, the word "free" was omitted from the specification, thus including water in emulsion or suspension within the limit. However, the test remained unchanged and the limit still remained as applying only to that water which was originally free or was freed by the action of the centrifuge.

IV. FLASH POINT.

The flash point requirement can be covered in a very few words. In order that all fire hazard should be eliminated the low limiting flash point was kept quite high, 200 degrees F. The figure was taken from the British Navy Specifications. For the fiscal year 1914, the figure was lowered to 150 degrees F. and at that point it has remained.

The one change was brought about by the Mexican fuel oil which has probably had more lasting effect on fuel oil specifications than any other factor. Due to its characteristics, the crude oil produced in Mexico brought a very low price. In many cases the gasoline fraction was so small that it did not pay refiners to remove it. Much of the Mexican oil was thus placed on the market as fuel oil in its crude state. The price was very low and extensive tests both on board ship and at the Fuel Oil Test Plant

demonstrated that the oil was a satisfactory naval fuel. The flash point of much of the oil was, however, as low as 80 degrees F. As a compromise and to broaden the supply of cheap oil, the Navy dropped its flash point limit to 150 degrees F. as stated above. At the time the change was decided upon, a board was appointed by the Secretary of the Navy to determine a safe minimum flash point for fuel oil for use on naval vessels. The precept of this board was dated 28 March, 1913, but its formal report was not submitted until 1 April, 1914, nine months after the lower flash point was put in use in purchase specifications. The board's investigation thoroughly covered every applicable phase of the question and it found that a minimum flash point of 150 degrees F. was satisfactory in all respects for naval purposes. The finding has never been questioned and no difficulty has ever been experienced, attributable directly to the lower flash point.

For the fiscal year 1915 the following requirement was added and has remained to the present:

"Flash point . . . and not lower than the temperature at which the oil has a viscosity of 8 Engler."

The insertion of the additional qualification is easily justified. Experiments at the Fuel Oil Test Plant had definitely demonstrated that the capacity of any boiler was a maximum when the oil, regardless of its other characteristics, entered the atomizer with a viscosity of 8 Engler. Naval Instructions at the time prohibited heating fuel oil above the flash point at any point outside the burner. Hence to permit operating at maximum capacity without nullification of the Instructions, it was necessary that any oil supplied to ships be capable of having its viscosity reduced to 8 Engler without heating it above its flash point.

In 1921 two events occurred which rendered the added requirement unnecessary but an apparent lack of realization of the reason for the requirement caused it to be retained. The two events were: (1) The Fuel Oil Test Plant, without necessarily questioning its former finding that 8 Engler was the atomizing viscosity for maximum *capacity,* determined that the viscosity for maximum atomizing *efficiency* was in the range between 2 and 4 Engler. This viscosity was adopted by the Bureau of Engineering for recom-

mended operating practice and at the same time (2) heating fuel oil above the flash point *between the heaters and the burners only* was permitted.

V. SPECIFIC GRAVITY.

As stated previously, the 1911 specifications carried an upper gravity limit of 30 degrees Beaume. During the discussions which took place on the original specifications, the need for a lower limit was brought out. The reasons given were not basically sound as they were founded on the assumption that gravity and viscosity were consistently correlative. That is, it was assumed that an oil heavier than a certain gravity would be too viscous for handling on board ship. All of the correspondence at the time shows that this was the trend of thought, that gravity was a measure of fluidity.

The result was a double limit for 1912. The upper limit of 30 degrees Beaume (.8755 specific gravity) remained unchanged and a lower limit of 18 degrees Beaume (.9465 specific gravity) was added. In the following year, experience having shown that the lighter oils were easier to handle and that it was very improbable that too light oils would ever be marketed as fuel oils, the upper limit was removed and only the requirement that the oil be not heavier than 18 degrees Beaume remained.

In 1914 the gravity requirement was dropped entirely. It has not reappeared as a specification requirement since that time except that for West coast purchases only, where the suppliers refused to furnish oil complying with Navy specifications, it was added to contract specifications for that coast in 1915, 1919, 1920, and 1921. This was really not a specification requirement but a descriptive detail of the fuel oil which the marketers had to sell.

In the Spring of 1932 gravity was applied as a temporary expedient to the specifications of one existing contract. The reason should be recorded while it is still fresh. The oil supplied on this particular contract proved unsatisfactory in use because when it was heated sufficiently to reduce the viscosity for atomization, heater fouling was accelerated to the point where flow was appreciably reduced or even stopped entirely in a very short time. Coincidentally, the Bureau of Construction and Repair raised the

question of oil and water separation. That Bureau's particular interest at the time was the result which could be expected when sea water was used as ballast in fuel oil tanks which might still contain some oil. A hurried investigation indicated that a five per cent differential in gravity between oil and water would permit ready separation. This led to the choice of .950 specific gravity (17 Beaume) as a lower limit. When this additional requirement was proposed to the contractor, he stated that if it was imposed it would exclude all of the type of oil which he was then supplying and which had caused the heater difficulty. Since it thus appeared that the specification of a lower gravity limit would not only provide for separation of oil and water but would affect the exclusion of the particular grade of fuel oil whose elimination was desired, the requirement was added as an amendment to the current contract and was also included in the specifications for purchase on the West coast for 1933. It is thus apparent that the gravity requirement was not added to obtain the direct value of a gravity limit but because it indirectly prevented the supplying of a particular objectionable type of fuel oil. Otherwise, the gravity requirement should have been added to all contracts outstanding at the time and should have been used for 1933 purchases on the East coast. Neither of these was done.

VI. VISCOSITY OR FLUIDITY.

The clause covering fluidity, previously quoted, was known as the "cold test." Efforts to reduce the temperature to 32 degrees F. to cover operating in the coldest climates were successfully resisted by the suppliers and the requirement remained unchanged for three years. In the 1914 specifications the only requirement which can be considered as applying to fluidity was the following:

"The right is reserved to cancel the contract in case such difficulties are met in pumping, handling and burning the oil in use as may, in the opinion of the department, render its use inadvisable."

In 1915 the first viscosity requirement appeared. It was specified as not greater than 200 Engler at 100 degrees F. Contracts exempted oil purchased on the West coast from this requirement.

The reason was not that the California oil exceeded the specification requirements as to viscosity because the limit was so high that had it been approached great difficulty would have been experienced in service. The California refiners did not have viscosimeters. In fact, they did not even have testing laboratories and chemists. Such was the state of the fuel oil business on the West coast.

The conventional methods of measuring viscosity, all measure the time required for a specified volume of oil to flow through a specified tube at a specified temperature. The tube is a particular feature of the instrument used. Hence in designating a viscosity measurement both the name of the instrument and the temperature of the oil must be stated. The Navy selected the German instrument known as the " Engler" as standard and specified 100 degrees F. as the test temperature. The standard instrument in general use in the United States was the Saybolt Universal Viscosimeter but it was used only for lubricating oils for which it was designed. The tube in the Universal was so small that excessive time periods were required for measuring the viscosity of many fuel oils.

In the fiscal year 1916, refiners on both coasts met the Navy specifications. The California refineries had obtained viscosimeters. In the same year a conversion factor was inserted in the specification for use where no Engler instrument was available. This factor gave 7000 seconds Saybolt Universal as equivalent to 200 Engler.

In the following year the viscosity limit was lowered by lowering the test temperature to 70 degrees F. while still specifying a maximum limit of 200 Engler. At the same time the equivalence factor was modified in the light of experience, to 7500 seconds Saybolt Universal equal to 200 Engler.

In the fiscal year 1918 the viscosity limit was again lowered, this time by retaining the temperature at 70 degrees F. and lowering the viscosity limit to 40 Engler which was stated as equivalent to 1500 seconds Universal.

The limit remained unchanged through 1921 when a new standard viscosimeter appeared and was generally adopted. This instrument was identical with the Saybolt Universal except for the dimensions of the flow tube which was larger, permitting reason-

able flow periods for tests of road and fuel oils. The instrument was designed for testing these two classes of oils and from that fact and its general design it derived its name " Saybolt Furol."

A digression is in order at this point to explain the division of fuel oil into grades which occurred in 1918. The Navy controlled its fuel oil specifications from the beginning of the war until August, 1918. During that period a large number of ships of merchant types had been taken over for use in the fleet and more generally for use as part of the Naval Overseas Transport Force. Only a small percentage of these vessels used fuel oil but those which did had been burning oil which was much inferior to Navy Specification Fuel Oil. On the advice of the Fuel Conservation Board, heavier and more viscous fuels were purchased for these ex-merchant ships. This procedure was necessary to conserve the limited supply of high grade fuel which was considered essential to combatant ships.

In August, 1918, President Wilson formed a Committee for the Standardization of Petroleum Specifications and ordered that all departments of the government should use the specifications promulgated by this committee. The committee recognized existing conditions and existing specifications and issued the governing standard as an exact reprint of current Navy Specifications. Four grades of fuel oil were covered. Grading was based on a double system due to the previously mentioned idea that viscosity and gravity were correlative.

The four grades were: " Navy Specification Fuel Oil," " Bunker A," "Bunker B," and " Bunker C." Bunker A was identical with the fuel oil which the Navy had been purchasing for combatant ships but some objection to sulphur fumes in the exhaust gases because of their effect on men in the mast platforms had been raised and the Navy Specification Fuel Oil was raised above the Bunker A by the addition of a sulphur limit. Bunkers B and C differed from the higher grades only in that there was no viscosity requirement and that the 8 Engler limit on flash point did not apply to them. A gravity requirement replaced the viscosity requirement and served for differentiating between the two lower grades. For Bunker B a lower gravity limit of 18 degrees Beaume was specified and for Bunker C an approximate limit of about 16 degrees.

At the time, the method of grading was satisfactory. The concordance between gravity and viscosity of oils marketed was sufficient to preclude the inclusion of one oil under all grades. That is, an oil with a gravity of 18 degrees Beaume would be too viscous to meet the requirement for Bunker A or Navy Specification Oil but this condition did not last very long.

This classification defect was remedied shortly after the war, when the committee, still functioning, changed the grading to a uniform viscosity basis. This grading is shown in the following table:

Navy Specification Fuel Oil	Viscosity not over 140 seconds Saybolt Furol at 70 degrees F.
Bunker A.	Viscosity not over 140 seconds Saybolt Furol at 70 degrees F.
Bunker B.	Viscosity not over 100 seconds Saybolt Furol at 122 degrees F.
Bunker C.	Viscosity not over 350 seconds Saybolt Furol at 122 degrees F.

For Navy Specification and Bunker A the only change made was in the instrument, since 140 seconds Furol is equivalent to 40 Engler. For the heavier grades, the viscosities were limited arbitrarily at 100 and 350 seconds Furol. The temperature, 122 degrees F., was carried over from laboratories where the use of the Centigrade scale was standard practice. The temperature is equivalent to 50 degrees C.

The above figures were all incorporated in Navy Department Specification 7–0–1 with which the Navy temporarily regained control of its own specifications.

The Interdepartmental Specifications Board, which interposed between the War Board and the Federal Specifications Board, issued a specification on 23 January, 1922. This specification differed only in minor details from the war specification. The laboratorians with a scientific bent obtained a change in the test temperature for Navy Standard (formerly "Navy Specification") and Bunker A from 70 degrees F. to 77 degrees F. (25 degrees

C.). To keep the viscosity requirement actually unchanged it was necessary to change the limit at this higher temperature from 140 to 100 seconds Furol. This was done. The only other change was the lowering of Bunker C from 350 to 300 seconds Furol.

The first revision of 7–0–1 was made to conform to the specifications of the Interdepartmental Board in the above details and no viscosity changes have been made since that time.

The introduction of grading to meet wartime necessities and its retention after the war is believed to have exercised a very important influence over the question of fuel oil supply for the Navy. This point will be more thoroughly discussed at a later time.

VII. CALORIFIC VALUE.

Fuel oil is purchased for its value in releasing heat energy in a boiler. This fact was originally recognized when the heat value was specified. The calorific value limitation was unchanged for three years when it was removed from the specification never to reappear.

The only reasons which can be adduced for the abandonment of the requirement are:

1. The recognized fact that the bomb test for determining calorific value did not correlate very well with service experience. That is, an oil with a high calorific value would not necessarily give greater power when burned, than would one of lower value. Very little consideration of all the other factors which affect boiler efficiencies is needed to explain this apparent discrepancy. Efficiencies and operating methods were perhaps not so thoroughly understood in 1914 as they are today.

2. The Bureau found that the actual variations in calorific values of all fuel oils was less than 5 per cent.

3. Formulae were available for approximating the calorific value of a fuel oil by use of the specific gravity alone. From the information available this appears to have been the governing reason for dropping the requirement. If so, the concurrent omission of the gravity requirement deprived the specification of any means of controlling thermal value.

ADDITIONAL REQUIREMENTS.

There has been only one requirement added to the specifications which was not covered at least qualitatively in the original 1911 specification. This requirement is contained in the following paragraph which was incorporated in the schedule for the fiscal year 1918:

"No residuum of any destructive distillation, or so-called 'cracking process,' to be mixed or included in fuel oil furnished the Navy under this contract."

The actual history of this clause, which became effective on 1 July, 1917, and was removed and discarded finally on 5 September, 1917, will probably always be shrouded in obscurity. As a quality requirement it is highly desirable but the restrictions on the quantity of fuel oil available under such a requirement would be increasingly great.

The requirement was included in the specifications on the recommendation of the Paymaster General of the Navy who stated that he had been advised by an unquestionable authority that the restriction was highly desirable to the Navy. It was removed two months later without comment.

THE PRESENT.

Earlier in this paper the conditions surrounding the supply of fuel oil in 1910 were briefly described. The Specifications which were drawn up to meet these conditions were quoted and the changes which the original specifications underwent were discussed.

Let us now consider the present conditions under the same seven heads as were used for the treatment of the older conditions.

1. *Economic Definition of Fuel Oil:*

There has been no change under this head. Fuel oil is still a refinery by-product.

2. *Physico-Chemical Definition of Fuel Oil:*

Fuel oil is still a physical mixture of hydrocarbons plus certain impurities but it is a very difficult matter to describe just what the hydrocarbons are chemically. Of course, there is still some of the former types of fuel oil on the market. Additional types have

entered and complicated the chemical description of the oil. Since practically no research has been done on the new types, nothing but hypothetical discussions can be made. The two added types are blends where a fluid oil and a viscous oil are mixed to give one of intermediate viscosity; and cracking still products, both distillates and residues, which may become fuel oils or fuel oil blend components.

Fuel oils of the latter kind apparently contain chemical constituents, probably hydrocarbons but possibly containing oxygen, nitrogen, or sulphur; which have two general undesirable characteristics—physical and chemical instability. The chemical instability in itself would probably not be undesirable but when chemical changes occur, the reaction products seem to lack physical stability. The result is that fuel oils when received may be physically unstable or, if this is guarded against, the instability may develop in storage or in some part of the fuel oil system.

In use, the result of the above mentioned physical instability is objectionable deposits, difficult of removal and deleterious to efficiency and capacity, in fuel oil tanks, piping, heaters and furnaces. Some of these deposits have actually been experienced by the Navy, others by commercial users, while still others are indicated by various refinery experiences.

3. *General Refinery Practice:*

It can be considered that but one major development has taken place to affect the refinery practice previously described. That is the art of "cracking" and its application. The increasing demand for gasoline has put an increasing strain on the supply of crude oil. The use of no other petroleum product has increased so rapidly nor so much. At times sufficient crude has been available to meet the gasoline demand by the former methods of distillation. At other times a shortage, or fear of an imminent shortage, of crude has threatened the supply of gasoline. Distillation of coal or shale and manufacture of alcohol can provide substitutes for gasoline but these substitutes are expensive. Cracking is relatively cheap and it can be, has been, and is being used to greatly increase the gasoline supply. In cracking, any heavier petroleum product is subjected to high temperatures and pressures which results in

a rearrangement of the molecules. In general, cracking divides the charging stock into two fractions: a distillate which is lighter than the charging stock, and a residue which is heavier. The process strives to make the lighter fraction as large as possible since from it come the gasolines and other light, valuable products. The heavier fraction, depending on the process, may be coke or it may be a liquid or semi-liquid which can be disposed of only as fuel oil.

Because of its high yield of gasoline when cracked, gas oil which was formerly available in fairly large quantities as a fuel or blending component of fuel oils, is very popular as a cracking charging stock and that use is gradually becoming its principal one. The former fuel oil residues are also more valuable to the refiner as charging stocks than as fuel oil.

The following table shows the classes of fuel oils available on the market at various times:

1910.	*1915–1925.*	*Present.*
1. Gas oil.	1–4. Same as 1910.	1–4. Same as 1910.
2. Topped crude.	5– . Blends of any of the above.	5. Cracked distillates.
3. Crude.		6. Cracked residues.
4. Reduced crude.		7– . Blends of any of the above.

Future.

1. Cracked distillates. 2. Cracked residues.
3. Blends of cracked distillates and residues.

4. *Extent of the Use of Fuel Oil:*

The same conditions exist on the Pacific coast as in 1910 except, of course, for increases in quantities used due to industrial growth. In addition, the naval fleet which in 1910 used but little oil now uses no coal and whereas its fuel oil demand was entirely in the Atlantic, it is now more than fifty per cent in the Pacific.

All over the world fuel oil is used by merchant ships instead of coal. In the United States more than half of the merchant fleet is fueled with oil.

The general use of fuel oil in the Navy and the ease which has always been found to characterize its use have resulted in a belief

among operating personnel that fuel oil is a commodity which need only be heated to a certain temperature and pumped to the atomizers in the quantities necessary to get the steam desired. There has been little realization that the nature of the fuel oil has changed in a great many cases. A large part of this belief is undoubtedly due to the fact that to date, the Navy has received very little of the unstable fuel oil which is becoming an increasing percentage of the whole.

5. *General Methods of Use:*

Probably the only changes have been the increasing complication of piping systems on naval vessels, the universal adoption of pressure mechanical atomization for all marine boilers, and the greatly increased horsepowers of installations.

6. *General:*

Unfortunately, the same remarks made for 1910 are applicable today except that the cry "wolf" has been raised so often that a very strong feeling is now general in some circles that the shortage will never come. The fear of a shortage of fuel oil of satisfactory *quality* has never been expressed.

7. *Existing Specifications:*

The Navy specifications as they were formerly recognized cannot be said to exist today. The so-called Navy specification is nothing more than a reprint of the Federal specification. The Navy has had a voice in the preparation of this specification but has lacked control.

CONCLUSIONS.

The above remarks, when taken in conjunction with the foregoing description of the specifications, disclose the fact that while fuel oil has become much more complex in its nature and its use and application have become somewhat more complex, the specifications covering its purchase have been progressively simplified. Is not an anomoly indicated?

A close study of the pertinent files proves beyond a doubt that the Navy has made every effort to reduce the cost of its fuel oil. Before the war each broadening of the specification was studied

and, where considered necessary, was submitted to experimentation to make certain that no military sacrifice was made to effect economy.

Two features of the World War required the grading of fuel oil for naval use. In the first place, a large part of the burden of supplying oil for the allied navies fell upon the United States. Thus, in effect, the demand on the United States for fuel oil for combatant ships was increased as much as though the Navy had held a reserve fleet equal to the allied fleets. Even for war expansion this was an unprecedented and probably never to be repeated increase. In the second place the location of the allied countries in Europe and our overseas army movement in the face of an active submarine campaign required that the merchant fleets be brought not only under naval control but under naval command.

Since practically all bunker fuel oil for ships had become *naval fuel,* it was necessary to grade it to prevent the unwise demand for true naval fuel for use by all types of vessels. Also, since the demand for true naval fuel itself was so greatly increased due to allies, it was necessary to broaden the specifications for this grade more than was desirable.

Had the end of the war permitted a return to pre-war conditions, it is at least possible that the Navy would have returned to its former policy of close scrutiny of fuel oil specifications. It is possible that the short-lived restriction against cracked fuel oils might have been resurrected and subjected to thorough study. It might be stated here that the Navy's scrutiny had always included a study of fuel oil sources and production methods.

The continuance of the war specifications committee in one form or another confused the specification question to such an extent that every Navy Department specification has included all of the grades of fuel oil which were born of the war. Even though the Navy knew that the storage problem forbade the use of more than one grade of fuel oil in the fleet, there were four grades of fuel oil under Navy specifications. The grade which still bears its name "Navy Standard" has not been purchased since the war. To specify it, at least such has been the fear, would mean to pay a premium price for fuel.

The Navy, following the Federal Specifications Board, has continued to use a specification which was prepared to cover an entirely different material than is today embraced in the name " Fuel Oil." The committee of the Board which has prepared fuel oil specifications has failed to recognize the change in fuel oil characteristics and the Navy through its membership on this committee has followed along. Even though the laxness of the Navy under the circumstances must be admitted if there has been any laxness at all, it is firmly believed that had the Navy been permitted to control its specifications entirely as it had before the war, the present situation would never have arisen.

To make the flat statement that the present specifications are useless would be presumptuous because it is *not known what fuel oil is today* nor how it must be handled. The flat statement will be made, however, that *it behooves the Navy to make a thorough study of fuel oil to determine these facts.*

MARINE BOILER DRUMS OF FUSION WELDED CONSTRUCTION.

By James Campbell Hodge, D.Sc.*

The many extensive experiments conducted by the Navy Department for the purpose of determining the suitability of welding as a constructional method have resulted in the wide application of the various welding processes in the fabrication of different types of engineering structures recently constructed or in process under government specifications. Considerable publicity has been given to the welding achievements of other nations in naval engineering. The details, however, remain obscure and it may be conservatively stated that the application of welding, and of metal-arc welding in particular, has progressed in this country to a greater extent than in any other in both civilian and governmental fields. During 1931 and 1932 forty-seven fusion-welded boiler drums were constructed for the U. S. Navy by the company with which the author is connected. In the fall of 1930 the Bureau of Engineering, U. S. Navy, adopted arc-welded construction for the joints of drums for 24 boiler drums now installed in the new scout cruisers *Minneapolis, New Orleans,* and *Astoria.* This approval of fusion-welded boiler drums by the Bureau of Engineering undoubtedly contributed to the final acceptance of welded drums by civilian engineering authorities about six months later. A brief discussion of the development of fusion-welded drums and of the properties of the welded seams in these drums should, therefore, be of interest to the officers and personnel of the U. S. Navy.

High pressures (1200 pounds per square inch) for steam generating units were introduced in the central power plants of this country about seven years ago, the previous existing maximum operating pressure being in the neighborhood of 700 pounds per square inch. Drums for this medium operating pressure had

* Chief Metallurgist, The Babcock & Wilcox Co., Barberton, Ohio.

been successfully fabricated by riveting, but the advent of the higher pressures demanded drums of greater wall thickness which could not be fabricated by standard riveting practices obtaining on the lower pressure drums.

The riveted joint had been developed to its limit with a maximum operating pressure of drums of this construction of approximately 750 pounds per square inch, using approved and standard grades of steel plates and rivets, and the advent of higher pressure steam brought about the introduction of forged seamless drums. The cost of these drums is, however, a considerable item in the cost of construction of the boiler due to the very expensive procedure required for manufacturing such drums—the drum must be forged from extremely large ingots requiring an enormous amount of hot working, numerous heatings of the ingot during forging, and expensive machining of the entire surfaces of the drums which entails a large loss of material to insure the removal of all surface defects caused by the forging operations.

The attention of the boiler manufacturer was, therefore, directed towards the rapidly developing welding processes as a method of joining rolled plate to produce a drum with the merits of the forged seamless drum without its disadvantageous high cost. It is significant that the welding experiments of the author's company were started shortly after the first high pressure seamless forged drums were installed in one of their boilers. The goal of the boiler manufacturer was the development of a method of joining which would be equally applicable to small low pressure drums and large high pressure thick walled drums. At that time forge-and-hammer welding, electrical resistance welding, and acetylene welding were considered and eliminated for the reasons enumerated below.

(1) FORGE AND HAMMER WELDING.

The process for making forge-and-hammer welded drums commercially limited the thickness of the drum to even less than the maximum thickness which could be successfully riveted. Metallurgical investigations and tests conducted on forge-and hammer welded drums showed the forged joint to be subject to wide variation with danger of large zones of incomplete fusion being ever present (Figure 1). In fact, disastrous failures of this type of

welded joint, due to defects of this nature, had occurred in presure vessels in the oil industry. This welding process was also limited to the joining of plate of low tensile strength, as the base material to be of good weldable quality must be low in carbon and other strengthening, alloying elements. Forge-and-hammer welded drums were also subject to wide dimensional variations in their process of manufacture; and the variations in diameter and out-of-roundness, which were inherent to this process, would have caused considerable trouble in the final fabrication and assembly of the boilers.

(2) ELECTRICAL FLASH AND BUTT WELDING.

This method was being successfully applied in the welding of tube ends for superheaters and similar constructions. In the Boiler Code of the American Society of Mechanical Engineers, this type of welded joint was considered equivalent to a forge-and-hammer welded joint as it is fundamentally the same, electrical resistance being used as the heating agent in place of a furnace or forge, and the same allowable working stress was permitted with this method of welding. This welding process gave excellent joints of 100 per cent joint efficiency and presented possibilities in its application to boiler construction. For example, successful welds had been made on pipes 14 inches $\times$ 1¼-inch wall thickness, giving a total cross sectional area of 52 square inches to be welded, requiring about 1500 KVA of welding transformer capacity. Approximately 25 KVA of welding transformer capacity and five tons of force are required for the welding of one square inch of cross section, so that to weld a circumferential joint on a drum 48 inches diameter $\times$ 2 inches wall thickness would require approximately 7500 KVA of transformer capacity and 1500 tons of push up force. From these figures it is apparent that the cost of equipment and power consumption in the welding of heavy sections is excessive, and this method was eliminated from consideration in the welding and main joints in pressure vessels.

(3) AUTOGENOUS WELDING.

The conditions pertinent to autogenous welding, including both acetylene and arc welding, were less easily defined. The advocates

of this type of welding were making enormous claims without having any substantial data to support those claims. In the main, therefore, autogenous welding had been applied to the repair of broken parts and to the manufacture of minor constructions, subject only to static loads of small intensity. Both of the autogenous processes, however, presented possibilities for pressure vessel welding.

The arc welding process and particularly metal arc welding, presented definite advantages: (1) Automatic welding machines were being developed for the deposition of the metal. (2) The heating of the work was kept at a minimum due to the extremely local heating of the arc. (3) Dangers from distortion of the finished work were not excessive. (4) The reasons for the defects in metal arc welding were gradually being brought to light, and with the causes of the defects understood it was only a question of developing methods for the elimination of these causes to produce good sound welded joints. Their elimination did not seem insurmountable and development and research work was therefore concentrated on the metal arc welding process.

ADVANTAGES OF WELDED PRESSURE VESSELS.

Provided a welded joint of excellent and unquestionable quality could be produced, welded pressure vessels possessed decided advantages over the riveted vessel:

(1) The welded joint could be made to give a higher joint efficiency. This is extremely important in those classes of vessels where the wall of the vessel is not weakened by a large number of openings. Vessels of this type are largely used in the oil and chemical process industries.

(2) Due to the elimination of buttstraps, of rivets and of the lap of drum heads within the shell, and due to the higher joint efficiencies, a considerable saving of plate material and a large reduction in the weight of the finished drum would result—an extremely important consideration for marine work. Comparative weights for the drums constructed for the United States Navy are as follows:

Welded Drum	10,000 pounds
Riveted Drum	13,000 pounds
Saving in weight	3,000 pounds

(3) Due to the elimination of buttstraps, of the inside lap of drum heads and rivet heads, the volume of a drum is slightly increased, and in construction serving for the transport of fluids as in a penstock, wall friction is considerably reduced, thus increasing the rate of flow through the vessel.

(4) Although the use of inside caulked riveted joints had eliminated caustic embrittlement from the riveted joints of steam drums, the use of welded joints presenting a smooth surface on the interior of a drum would entirely eliminate the possibility of caustic embrittlement of the connecting joints. Dangers from local corrosive attack around the more highly stressed rivet holes would be eliminated.

However, in spite of the advantages of welded pressure vessels enumerated above, an autogenous welding process had yet to be developed giving welded seams with properties suitable for pressure vessel construction, an objective which had not up to that date been obtained by any of the autogenous welding processes then in vogue. Moreover—the various governing groups of engineers were opposed to the application of fusion welding to pressure vessels, due largely to the misuse of the electrical arc fusion welding process by prematurely enthusiastic advocates of this process. Much research work had, therefore, to be done in development of a suitable welding process and in obtaining reliable data regarding the physical and chemical properties of various types of welded seams from which rigid specifications governing the construction of fusion welded drums could be drawn.

PROPERTIES OF WELDED SEAMS OF PRESSURE VESSELS.

The development of a suitable welding process was started with the premise that the welded seams of pressure vessels must be at least equal in quality to the plate material in every respect. The welded seam should be as strong or stronger than the plate material. The weld metal should be tough and ductile. The welded seam should possess an endurance limit equal to that of the plate material. No great differential should exist between elastic properties of the plate material and the weld metal. Objectionable auxiliary phenomena such as embrittlement of the affected zone of the plate material should be absent.

The above requirements for strength presupposes a sound welded seam free from major defects; the requirements for toughness and ductility requires in addition a weld metal free from oxides and nitrides such as are normally absorbed from the atmosphere by molten weld metal deposited from bare electrodes without a protective slag or atmosphere around the arc; a high endurance or fatigue limit requires the production of weld metal free from porosity and even microscopic cracks, voids and inclusions which under repeated stress might act as nuclei for the origin and propagation of fatigue cracks.

Bare electrode arc weld metal usually contains a large number of microscopic defects such as porosity, slag, incomplete fusion, etc. (Figure 2), and in addition the weld metal is inherently brittle due to the presence of nitrides and oxides as shown in photomicrograph (Figure 3), in which oxides appear as small round inclusions and the nitrides as the elongated needle-like constituent. Due to the presence of major defects and undesirable microscopic constituents, bare electrode weld metal possesses a variable tensile strength and ductility and impact resistance of low values. Typical physical properties of bare electrode weld metal may be taken as follows:

Ultimate Strength, 50,000 pounds per square inch ±.
Elongation in 2 inches, 5 to 18 per cent.
Reduction in Area, 15 per cent.
Charpy notched impact value, 1 to 8 foot-pounds.
Per cent elongation outside fibers in bend test, 5 to 10 per cent.

The above presentation of data regarding the bare electrode metal arc welding process should not be interpreted as a rejection of this process for all classes of arc welding fabrication. For those types of engineering structures subject to only relatively low static loads, the bare electrode arc welding process may be successfully employed. Where, however, the welded seams of a structure are subject to impact and repeated stresses, are subject to corrosion, or operate in the blue brittle range as in boiler drums, an arc welding process giving suitable protection to the molten weld metal from the atmosphere during its deposition must be employed in the production of those seams.

The following metallurgical and chemical properties of welded seams are presented as characteristic of welded seams obtained by such a protected metal arc welding process, employed, of course, under rigid control, as will be discussed later.

Figure 4 shows a macro section through a welded seam, showing freedom from porosity, entrapped slag, incomplete fusion and other major defects, as contrasted with typical defects of the bare electrode metal arc welding process, as shown in Figure 2. The micro structure of this weld metal at a magnification of 500 diameters reveals a fine grained equiaxed structure free from objectionable nitrides and oxides.

The values given for the tensile, impact and bend test properties of the welded seams were obtained on specimens cut from an excess length of seam in a shell for one of the boiler drums fabricated for the Navy scout cruisers under Navy specifications. The plate material used was Class A, Marine Boiler Plate, with a tensile range of 60 to 70,000 pounds per square inch.

TENSILE PROPERTIES.

Two types of tension test specimens are used in the testing of a welded seam. The first type of specimen is cut transverse to the welded seam and therefore determines the comparative strengths of the weld metal, fusion zone, affected zone of parent metal, and the unaffected parent metal. Figure 6 shows seven transverse tension specimens from welded marine plate, the maximum, minimum and average tensile properties of the plate material and weld metal as obtained from these specimens being presented in Table I.

TABLE I.

	Plate			Weld Metal		
	Max.	Min.	Ave.	Max.	Min.	Ave.
Ultimate Stress pounds per square inch	65600	63100	64770	65950	65750	65830
Yield Point square inch	42500	40200	40940	50200	48200	49200
Reduction of Area per cent	55.2	52.3	53.6	55.8	48.8	53.6
Elongation in 1 inch across fracture	60.0	55.0	57.5	48.0	46.0	47.3

These values are quite uniform and the physical properties of the two steels comprising the welded seam are remarkably similar.

This is clearly indicated by four specimens failing in the plate material and three in the weld metal, and is further illustrated in the photograph of the fractured specimens, which show a uniform elongation and reduction of section across the weld in those specimens where failure occurred in the plate.

The second type of tension test specimen is an all weld metal specimen of standard dimensions .505-inch diameter by 2-inch gauge length, cut from the weld so that the axis of the specimen is parallel to the axis of the joint, this type of specimen being used primarily to determine the ductility of the weld metal.

The modulus of elasticity of the weld metal has been found by repeated stress-strain measurements to be exactly the same as that of steel, and inasmuch as structures are stressed in service within the elastic range, no concentration of stress can possibly exist at the welded seams.

BEND TESTS.

The bend test specimen is transverse to the welded joint and is of considerable value in determining the ductility of the weld metal. The specimen is bent under free bending conditions and the ductility of the weld metal is expressed as the per cent elongation of the outside fibers of the weld metal during bending.

Five bend specimens, so tested, are shown in Figure 7, each specimen having been bent 180 degrees to a maximum inside radius of bend of 0.8 inch, and with deformation of the weld metal equivalent to elongations of the outer fibers of 47.5 to 62.5 per cent.

IMPACT RESISTANCE.

Notched impact tests give a measure of the degree of toughness or the degree of brittleness of a metal. Table II gives comparative impact values for three steels of interest, these values being obtained on standard Charpy impact specimens with key-hole notch.

TABLE II.

	Min.	Max.	Ave. ft. lbs.
Boiler Plate	19	33	20
Weld Metal—bare electrode	1	8	5
Pressure Vessel Weld Metal	20	45	28

SPECIFIC GRAVITY.

The density or specific gravity of various weld metals offers a very convenient method of determining the relative amounts of voids or porosity present in weld metals.

	Specific Gravity			Average Density
	Min.	Max.	Ave.	lbs. per cu. ft.
Bare Electrode Weld Metal	7.44	7.68	7.59	473
Pressure Vessel Weld Metal	7.80	7.85	7.83	488
Boiler Plate	....	....	7.84	489

Assuming the theoretical value of the specific gravity of solid rolled low carbon plate as 7.85, the above values correspond to the presence of 3.3 and 0.12 per cent voids respectively in ordinary weld metal and the special pressure vessel weld metal. The minimum value of 7.44 for bare electrode weld metal corresponds to the presence of 5.2 per cent voids.

GRAIN STRUCTURE AND PHYSICAL PROPERTIES OF THE AFFECTED ZONE OF THE PLATE MATERIAL.

Considering the extremely high temperatures of the metal arc it is but natural for the layman to assume that the plate material along the fusion zone must be adversely affected. Due, however, to the extremely high thermal capacity of the relatively large plate being welded, as compared with the arc, and to the short period of time in which the arc is in contact with the plate at any point, the grain structure of the plate is only changed for a short distance from the line of fusion as shown in Figure 8. Some overheating of the plate occurs on single bead deposition in this small affected zone immediately adjacent to the line of fusion, but in building up a welded seam by deposition of layer of weld metal upon layer of weld metal, the heat of a bead being deposited refines the grain structure of the previously deposited bead and its adjacent coarse grained affected zone of plate material. For example, the grain structure of the first deposited weld layer will possess a coarse cast columnar structure (Figure 9-A), and its adjacent plate affected zone will show a coarse sorbitic structure for a distance of approximately 0.03 inch from the line of fusion

(Figure 9-B). The heat from the second bead deposited will, however, bring the metal of the first layer and the affected zone adjacent to the first layer above the critical range of the steel, thus refining the grain to produce an extremely fine grained weld metal structure (Figure 10-A), and varying degrees of refinement of the affected zone of the plate material (Figures 10-B to 10-E). Due to this grain refining action of multiple bead deposition, the bulk of the weld metal and the affected zone possesses a fine grained structure. Any coarse grained zones are of small amount and, moreover, sorbitic in structure, and as such possess excellent physical properties. Specimens of plate material have been heat treated to produce coarse grained structures such as exist in small amounts and at scattered points in the affected zone of the plate material of a welded seam, and have been found to possess excellent tensile and impact values. Impact specimens with the notch positioned at progressive points from the original unaffected boiler plate, through the affected zone of the boiler plate, through the line of fusion between boiler plate and weld metal, to the weld metal (Figure 11) have shown excellent values throughout, and superior values in the affected zone to the values of the original boiler plate.

It is apparent that the last bead deposited is not subjected to any annealing temperature, and for this reason the weld metal is built at least one layer above the surfaces of the adjoining plates and this coarse grained last layer removed.

CORROSION FATIGUE AND CAUSTIC EMBRITTLEMENT.

Comparative values for fatigue and corrosion fatigue of weld metal and boiler plate are presented in the following table:

	Fatigue Limit	
	Air	Water
	Pounds	Pounds
Boiler Plate	25–32,000	14–17,000*
Weld Metal	28–31,000	14,000†

* Fatigue and Corrosion Fatigue of Metals, J. D. McAdams, Jr., International Congress for Testing Materials, Amsterdam, September, 1927.

† Corrosion Fatigue Study of Welded Low-Carbon Steel, W. E. Harvey and Jerome Whitney, Journal of the American Welding Society, October, 1932.

Comparison of the above values indicates that the weld metal behaves identically the same as boiler plate under stress reversals in both air and in contact with water (Corrosion fatigue). The corrosion fatigue limit of this type of weld metal in fresh water has also been recently determined by the Naval Engineering Experiment Station, the reported value being in the neighborhood of 18,000 pounds per square inch.

It should be noted that the above limits are based on reversals of stress representing a complete cycle of stress from a compressive stress of the order indicated to a tensional stress of the same value. The variations in stress in boiler drum service are not reversals of stress, being in one direction only. A corrosion fatigue limit of 14 to 18,000 pounds per square inch under reversals of stress (Test conditions) may be considered as equivalent to a very much higher value under repeated applications of stress in one direction, as encountered in boiler drum service due to variations of internal pressure.

McAdams believes that the caustic embrittlement failures of certain riveted boiler drums are essentially corrosion fatigue failures. Other authorities believe, however, "That the essential differences which exist between actual boiler conditions and the conditions of corrosion fatigue tests, the data of which would form the only basis of comparison, do not justify any definite statement concerning the relation between boiler failures and corrosion fatigue." * Regardless of the difference of opinion between various authorities on fatigue, the above values for the corrosion fatigue limits of boiler plate and weld metal indicate that the weld metal should be no more susceptible to corrosion fatigue in service than boiler plate.

CHEMICAL ANALYSIS AND CORROSION OF WELD METAL.

The chemical composition of pressure vessel weld metal as compared with boiler plate and with bare electrode weld metal is given in Table III.

* Corrosion Fatigue of Metals, H. J. Gough, Autumn Lecture, 1932, Institute of Metals.

TABLE III.

	Firebox Plate	Pressure Vessel Weld Metal	Bare Electrode Weld Metal
Sulphur	Less than .04	Less than .045	Less than .045
Phosphorus	Less than .04	Less than .040	Less than .040
Manganese	.30 to .60	.30 to .60	Less than .20
Carbon	not over .30	.08 to .15	.02 to .08
Nitrogen as iron nitride	Not specified, will not usually be over .009	Less than .035	.10 to .14

The high manganese and relatively low nitrogen contents of the pressure vessel weld metal as compared with the bare electrode weld metal indicates excellent protection from oxidation and absorption of nitrogen during deposition. Repeated tests have shown that no microscopic nitrides are present in weld metal of less than .035 per cent nitrogen and that the corrosion resistance of the weld metal is not adversely effected. Higher nitrogen contents, however, result in the presence of microscopic nitride needles and accelerates the corrosion of the weld metal.*

FATIGUE TESTS OF WELDED PRESSURE VESSELS.

All of the foregoing deals essentially with the properties of welded seams as determined by laboratory tests on relatively small test specimens. While the values reported for each property had been repeatedly verified, it was deemed desirable to subject full sized test drums or shells of different types of construction, including fusion-welded construction, to repeated applications of internal pressure, thus simulating to some extent the variations in internal pressure of boiler drums in service.

Full sized test drums of riveted, forge welded, and forged seamless drum construction, and of fusion-welded construction were tested under repeated applications of pressure until either failure by fatigue developed or until a sufficiently large number of applications had been made to multiply manifold any cycle of stresses which might be encountered in boiler drum service. To date a total of thirty-one experimental drums have been so tested and their results compared. Much was learned about pressure vessel

* Chemistry of Low-Carbon Metal-Arc Weld Metals, J. C. Hodge, Journal of the American Welding Society, October, 1932.

design. For example, the riveted drum of standard construction withstood over 1,000,000 applications of a pressure equivalent to a stress across the joint of 16,500 pounds per square inch without failure. Many of the drums failed due to concentration of stress around a small hydraulic gauge connection hole after approximately 500,000 applications of a cycle of stress from zero to 16,500 pounds per square inch, this number of cycles being surprisingly constant for all drums which failed in this manner. The early fusion-welded drums failed after varying number of pressure applications, depending upon the types of defects present in the welded seams. For example, the test drum with welded seams deposited from bare electrodes failed after 5530 pressure applications (Figure 12). Another failed after approximately 250,000 pressure applications, the failure originating in and occurring through an elongated slag body, such as would now be revealed by X-ray examination.

After several attempts a fusion-welded test drum was made which withstood over 2,000,000 pressure applications without failure. These results could be duplicated at any time, and it was considered that welded drums constructed by the same welding process under suitable procedure control were entirely satisfactory for boiler drum service.*

SPECIFICATIONS FOR FUSION-WELDED DRUMS.

The above investigations were evidence of the satisfactory performance of fusion-welded seams for boiler drums. At that time, however, no satisfactory specifications for fusion-welded drums were available. In the then existing specifications some three or four pages were devoted to the requirements of the plate material, while the welded seam requirements were usually confined to the statement that the tensile strength of the weld shall be not less than that of the plate—certainly an unbalanced specification for fusion-welded drums if we consider that the welded seam meets the same stresses and conditions of service as the plate material.

After a number of years of study and discussion, the Boiler Code Committee of the American Society of Mechanical Engi-

* For further reference to these fatigue tests, "Tests of the Resistance to Repeated Pressure of Forged, Riveted and Welded Boiler Shells," H. F. Moore, Trans. A. S. M. E., Jan.-April, 1031.

neers proposed rules for the fusion welding of power boiler drums, these rules being based on a testing procedure which included—

1. Determination of the physical and chemical properties of representative sample welds.
2. Non-destructive examination of the welded seams by X-ray examination.
3. Hydrostatic testing of the finished welded drums.

Representative welded sample plates are obtained by tack welding sample plates to the ends of a longitudinal joint in the drum shell. Figure 13 shows the first fusion-welded boiler drum shell with these test plates on the ends of the joint. Deposition of the weld metal is made continuously through the main joint and sample joints, so that the welded seams of the test plate are thoroughly representative of the main weld seams of the shell. From these test plates the various test specimens are obtained.

After the completion of the welding of a drum or vessel, the main welded seams are subjected to X-ray examination. Any defects revealed by the X-ray are removed and rewelded, and the seams again X-rayed, if any repairs have been made. Figure 14 shows a 4⅛ inch thick welded drum in position before X-ray apparatus with 300,000 volt tube. Several typical defects in welded seams as revealed by X-ray examination are presented in Figure 15. After X-ray examination of the welded seams, the drums are stress relieved at approximately 1200 degrees F. and are then ready for hydrostatic test and for the machining of tube holes and other openings.

The specifications, under which the welded boiler drums for the U. S. Navy were constructed, are essentially as outlined above. It is of interest to note that under these specifications a welding procedure with its emphasis upon the minute details of shop practice is not specified but a definite and rigid testing procedure for determining the physical properties and soundness of the finished welded seam is specified.

DESTRUCTIVE HYDROSTATIC TEST OF WELDED PRESSURE VESSEL BUILT IN ACCORDANCE WITH THE SPECIFICATIONS.

The results of a hydrostatic test on a welded pressure vessel built in accordance with the specifications should be of interest. A welded

test drum 47⅛ inches O. D. × 1 inch thick × 14 feet 1 inch overall length was built in accordance with the specifications adopted by the Bureau of Engineering, U. S. Navy. The drum possessed one longitudinal seam and two circumferential or girth welded seams for the attachment of the heads to the shell. The welds were of the same thickness as the plate; that is, all of the excess weld metal had been ground off flush with the plate. During the hydrostatic test the drum was subjected 14 times to a pressure of 2830 pounds per square inch, the pressure in each case being raised from zero. Failure of the drum did not take place but the shell bulged outwardly to give an increase in diameter of the shell at its center of approximately 4½ inches, the elongation of the circumference of the shell at this point being 14 inches from an original circumferential length of 148 inches, corresponding to a mean circumferential elongation of 10 per cent (Figure 16).

Based on a factor of safety of 5 and considering the plate material had an ultimate tensile strength of 55,000 pounds per square inch, the working pressure of the drum was 489 pounds per square inch. Assuming that the yield point of the plate material was 33,000 pounds per square inch, the pressure at which the yield point of the shell was reached was 1021 pounds per square inch. The above maximum test pressure of 2830 pounds per square inch corresponds to a maximum hoop stress in the shell of 63,450 pounds per square inch based on the original diameter of the shell, and corresponds to 69,860 pounds per square inch based on the final diameter of the shell.

WELDING PROCESS USED IN THE MANUFACTURE OF WELDED DRUMS.

The welded seams described in this paper are deposited from heavy flux coated electrodes. The weld metal of the main longitudinal and circumferential welded seam is deposited by automatic welding machines, which move the arc along the seams at any desired speed and which maintain a constant length arc, thus eliminating to a great extent the human element of the welding operator. The deposition from the covered electrodes by the automatic welding machine is continuous. Manual welding is used for the welding of nozzles and other connections to the drums. A. C. welding

current is used in preference to D. C. welding, as no troublesome magnetic fields are set up with A. C. welding such as are encountered with D. C. welding.

In some of the recently constructed boiler drums, the drum is fabricated with each head formed from the extended cylindrical shell rolled or hot spun inward to the required form (Figure 17). Inasmuch as this operation is done at normal forging temperatures where the average metal arc welded metal is red short, this operation in which the welded seams at the ends of the cylinder or shell are hot worked, is evidence of the excellent metallurgical characteristics of the weld metal is these drums.

The foregoing is a necessarily brief description of extensive investigations conducted in the development of safe fusion welded boiler drums and similar pressure vessels. The more important metallurgical considerations have been covered in sufficient detail to indicate that the acceptance of fusion welded seams for boiler drums was based on a thorough study of the properties of welds with the resultant development of welded seams equivalent in all properties to that of the parent boiler plate.

The above welding process has been used in the construction of approximately 650 fusion welded boiler drums and has also been applied in the production of welded pressure vessels of widely varying sizes and for widely varying service conditions in the oil industry and in chemical processing. The rigid control of the quality of the welded seams involving repeated laboratory tests and the use of X-ray examination as a routine production inspection procedure assures the reliability of these welded boiler drums and pressure vessels in service with an ample factor of safety.

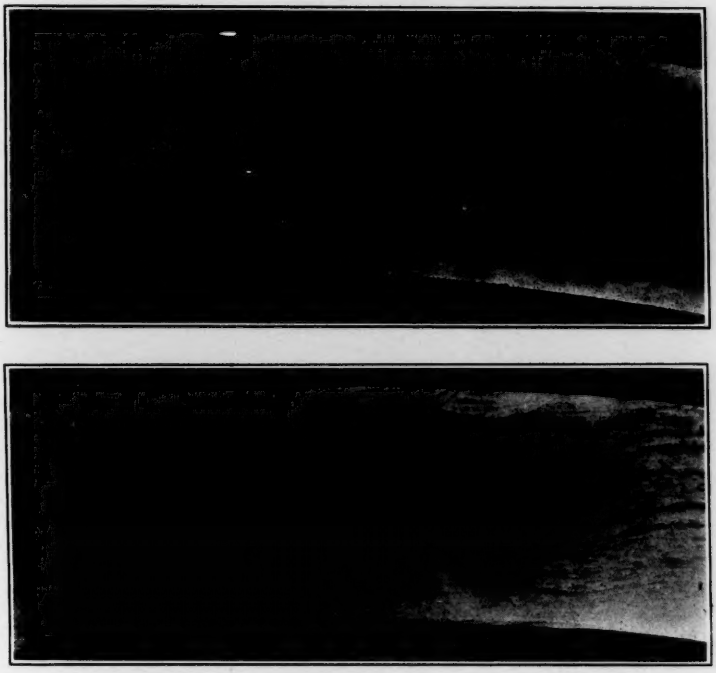


FIGURE 1.

Macrosections through Forge-and-Hammer Welded seams on 2-inch-thick plate—showing incomplete fusion along weld plane and crack due to forging at extremely high temperature (Etched-Ammonium Persulphate).

FIGURE 2.

Macro section of welded seam deposited from bare electrodes, showing typical defects (Etched, Ammonium persulphate).

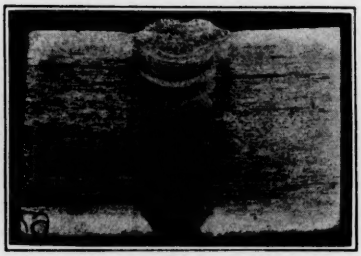


FIGURE 4.

Macro structure of welded seam, free from major defects, suitable for pressure vessel service (Etched, Ammonium persulphate).

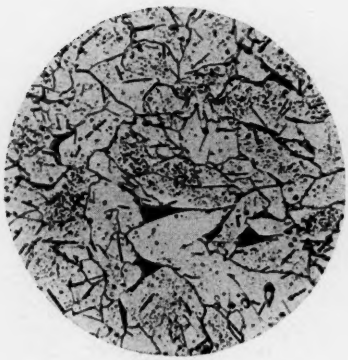


FIGURE 3.

Typical michostructure of bare electrode weld metal showing rounded oxide inclusions and needle-like nitride constituent (500X).

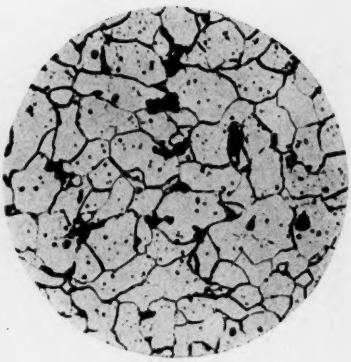


FIGURE 5

Typical microstructure of pressure vessel weld metal showing equiaxed structure and freedom from nitrides and oxides (500X).

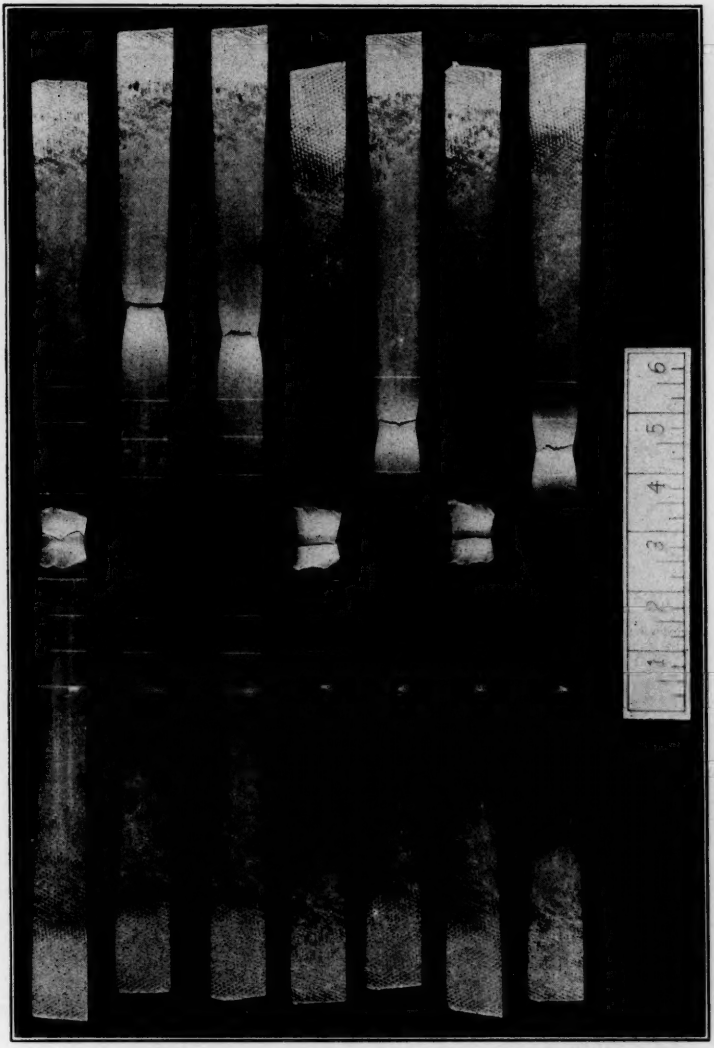


FIGURE 6.

Transverse tension specimens from welded marine plate, showing uniform behavior of plate and weld under deformation (Etched after testing).

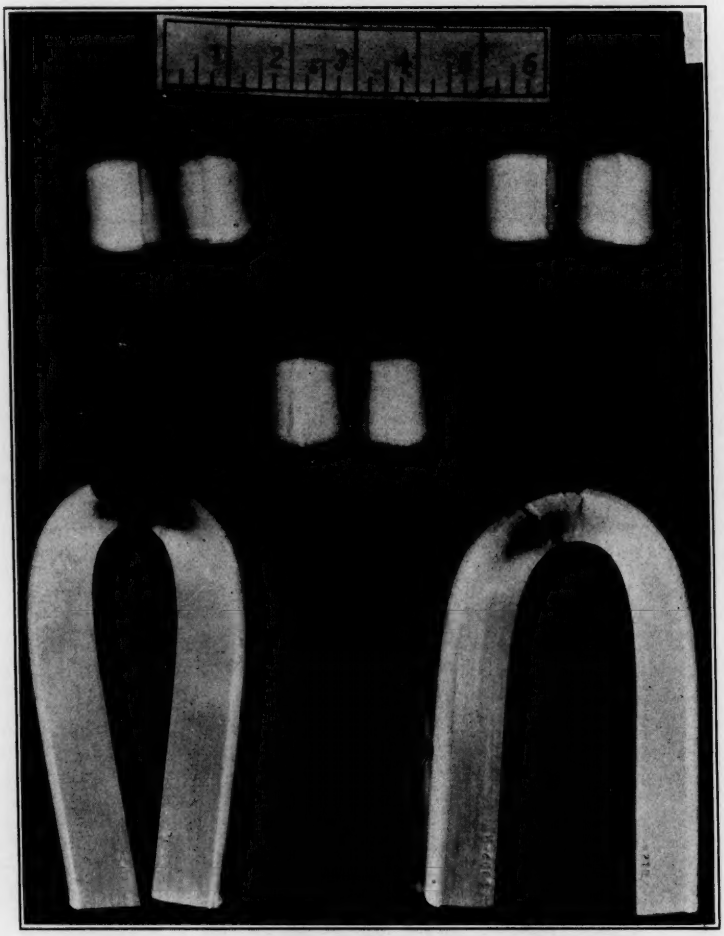


FIGURE 7.

Five bend test specimens from welded marine plate. Elongation of outer fibers—47.5 to 62.5 per cent.

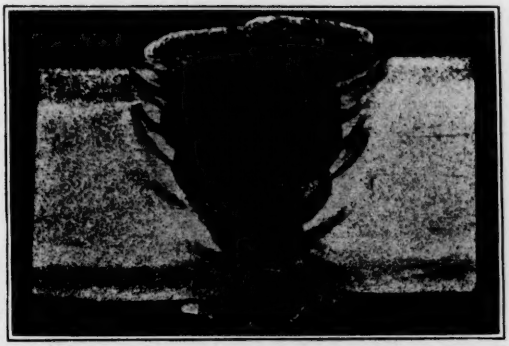


FIGURE 8.
Macro section through welded seam, etched to show affected zone of plate material (Full size).

FIGURE 9-A.
Original coarse cast columnar structure of weld metal (Single layer) (100X).

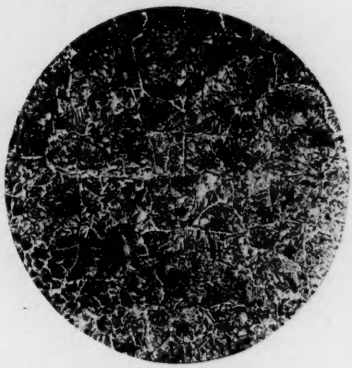


FIGURE 9-B.
Original coarse overheated structure of plate material adjacent to line of fusion (100X).

FIGURE 10-A.
Fine grained equiaxed structure of weld metal in multiple bead weld metal (100X).

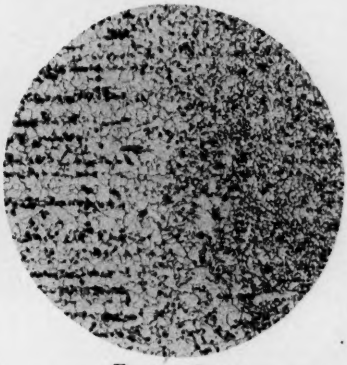


FIGURE 10-B.
Fusion zone between weld metal and plate material (100X).

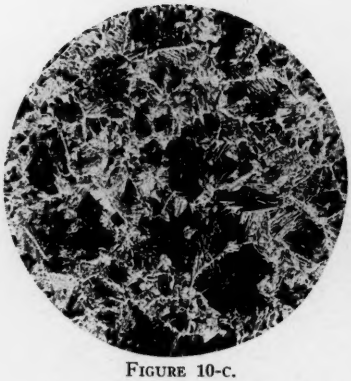


FIGURE 10-C.

Coarse sorbitic structure of affected zone near line of fusion. Present only in extremely small quantities (100X).

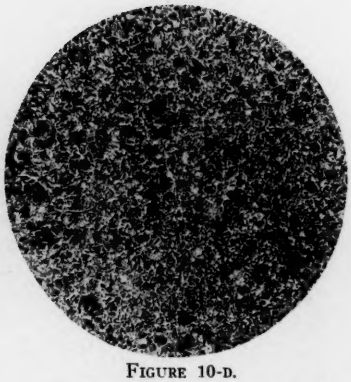


FIGURE 10-D.

Fine grained structure of affected zone near line of fusion. This structure typifies bulk of affected zone (100X).

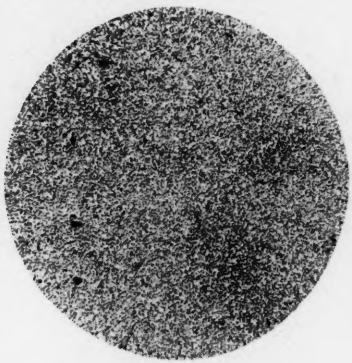


FIGURE 10-E.

Extremely fine grained structure also present in affected zone (100X).

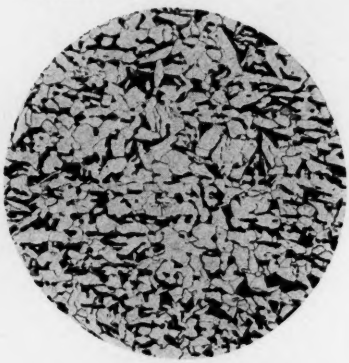


FIGURE 10-F.

Original structure of hot rolled boiler plate.

FIGURE 11.

Method of studying the relative toughness of the original plate, the various parts of the affected zone, the fusion zone and the weld metal.

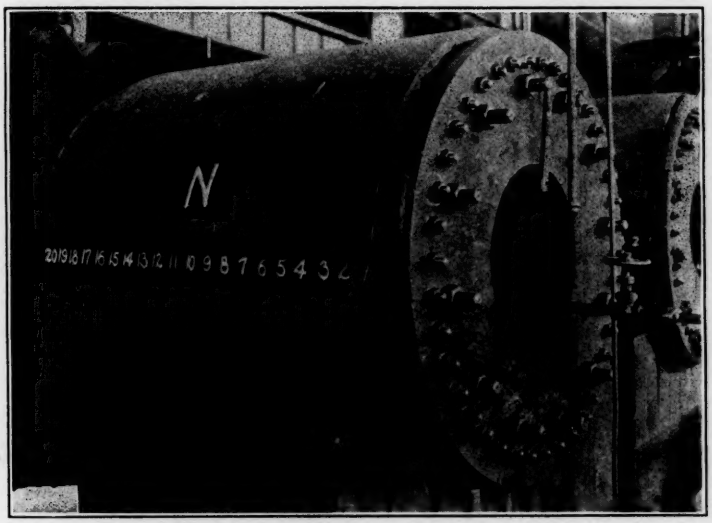


FIGURE 12-A.

Test assembly for repeated pressure test on full sized welded shells.

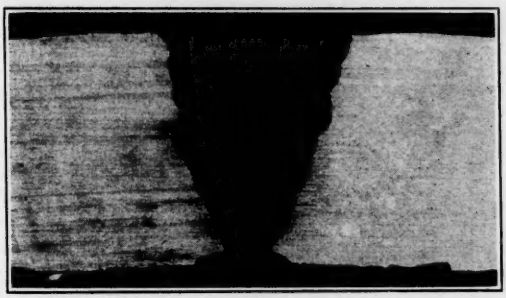


FIGURE 12-B.

Section through welded seam from fatigue test shell, welded with bare electrodes. Fatigue crack developed through defects along line of fusion after 5530 pressure applications.

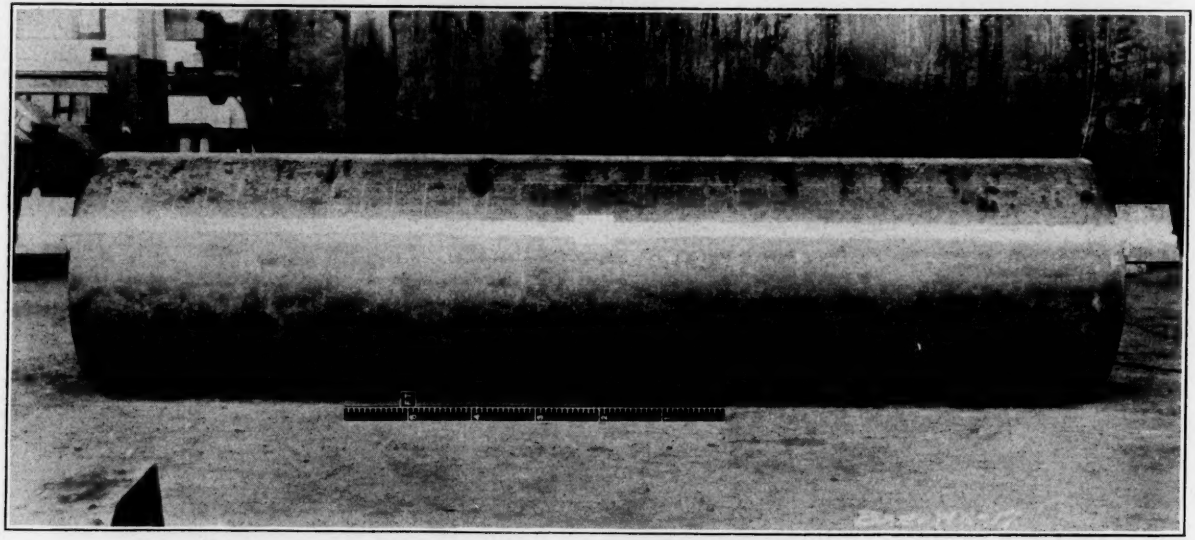


FIGURE 13.

Test plates attached to ends of longitudinal joint in shell of drum.

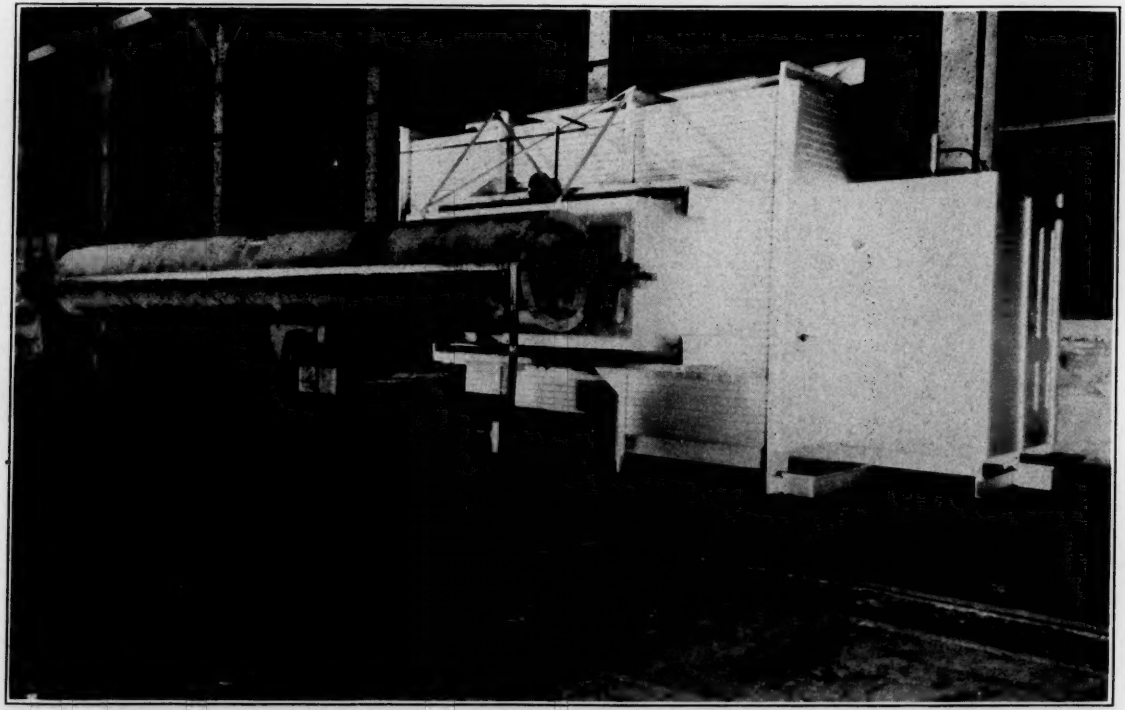


FIGURE 14.

Four-and-one-eighth inch thick welded shell being X-rayed. X-ray powerplant capable of delivering 550,000 volts. Limited at present by capacity of X-ray tube (300,000 volts).

FIGURE 15-A.

X-ray print showing porosity—not acceptable.

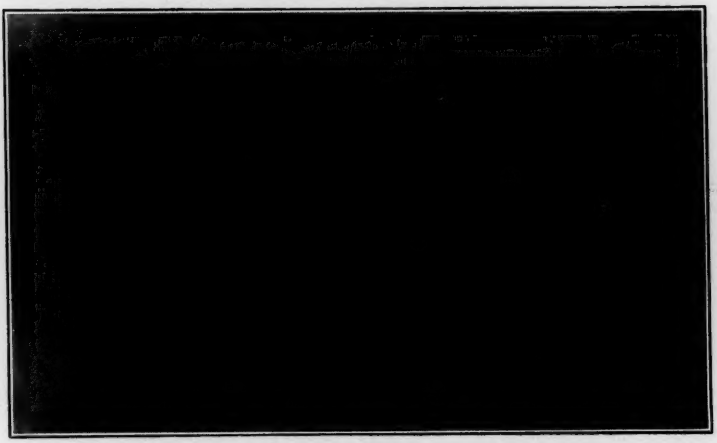


FIGURE 15-B.

X-ray print showing elongated slag body along wall of joint—not acceptable.

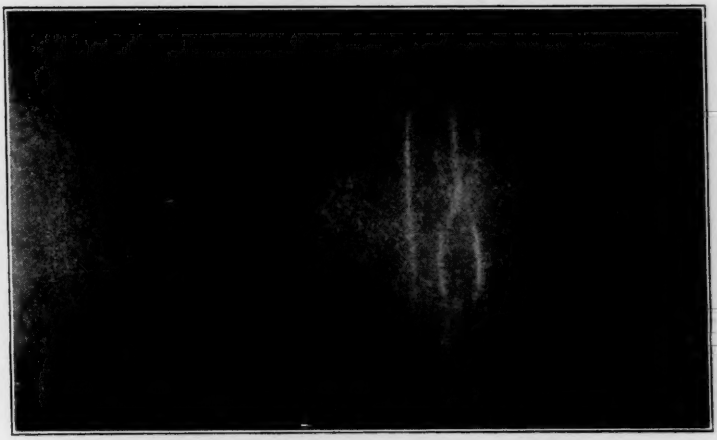


FIGURE 15-C.
X-ray print showing transverse cracks across welded seam.

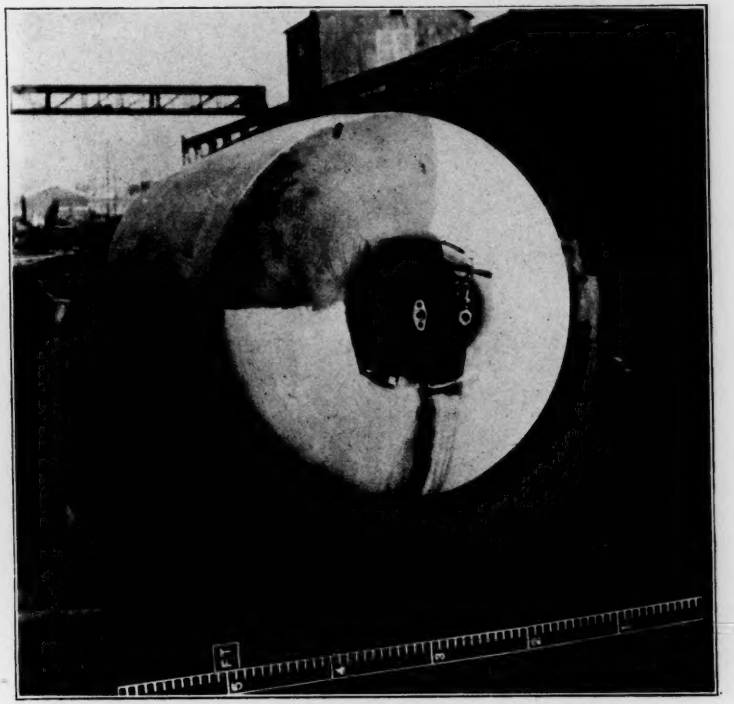


FIGURE 16.
Test drum after hydrostatic test, showing bulging of shell of drum. Designed working pressure 489 pounds per square inch. Test pressure, 2830 pounds per square inch.

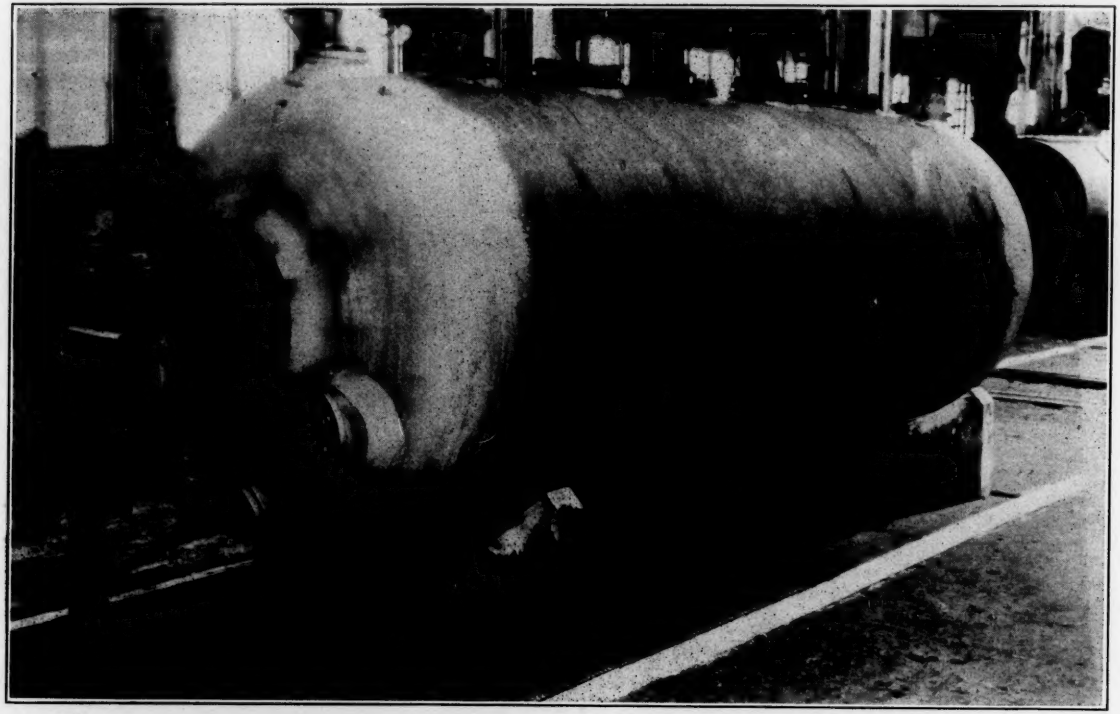


FIGURE 17.
Showing new type of construction of welded drum with spun-in heads.

BASIS AND METHOD OF DETERMINING A. C. CABLE SIZES.*

By Lieutenant Commander Louis Dreller, U. S. N., Member.

The initial installation of alternating current ship service electric plants on the destroyers under construction has introduced a number of very interesting electrical problems. One of these problems encountered early in the construction of the ships was the necessity for establishing a basis and uniform method for determining the sizes of lighting and power feeders and mains based on good engineering practice.

The problem is to specify cables large enough to carry the load without overheating and without too great a drop in voltage from the generator to the load. However, unless the determination is accurately made and unless the factors influencing the size of cables are properly analyzed the tendency will probably be to specify larger cables than necessary and result in an increase of weight in the cable installation.

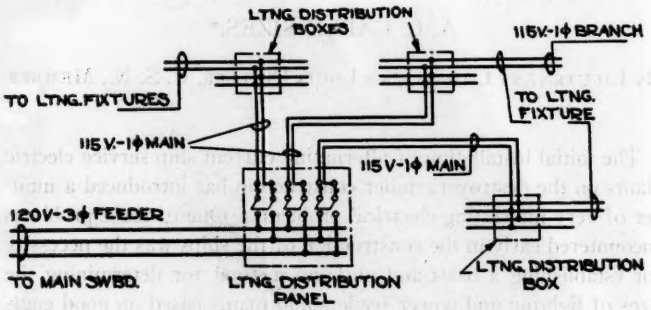
The methods for determining the size of feeders and mains for ship D. C. systems are well covered in the existing Bureau of Engineering general specifications and are known from experience to give a satisfactory installation. In A. C. installations, there are, however, a number of factors not present in D. C. installations that influence the size of the cables; namely, power factor, reactance of the circuit, and the heavy starting current of induction motors. In the determination of the cable sizes an attempt has been made to give each factor involved its proper weight in the analysis of the problem.

The generators of the destroyers are Y wound, three phase, 60 cycle, 230/120 volt machines. The 120 volt lighting buses are

* The writer wishes to thank Mr. E. C. Alger, Chief Electrical Draftsman, Fore River Plant of the Bethlehem Shipbuilding Corporation, and Mr. W. B. Armstrong, Engineer (Electrical), of the Bureau of Engineering, Navy Department, for their recommendations and aid.

Showing new type of construction of welded drum with spun-in heads.

tapped off the winding of the machine. This method of obtaining the 120 volt lighting circuit saves the weight and space that would otherwise be required for lighting transformers.



LIGHTING DISTRIBUTION SYSTEM.

Three Phase, 120 Volt A. C. Lighting Feeders and Single Phase 115 Volt Mains and Branches.

1. All loads are considered in determining wire sizes, including allowance for spare switches on the distribution panels and spare outlets in the distribution boxes. No allowance for spares is made for feeder junction boxes. The allowance for spares shall be as follows:

(a) All spare switches on distribution panels included in loads. Each switch load is considered as 33⅓ per cent of its rating.

(b) Spare outlets in distribution boxes included in loads (each spare outlet considered as a 50-watt lamp—0.43 amperes).

2. All single-phase (2 wire) mains, sub-mains and branch cable sizes are determined on the same basis as for direct current. The current in these cables is considered as the arithmetic sum of their loads, since the currents are all in phase. The total voltage drop on a single phase circuit is the sum of the voltage drops on the main, sub-main or branch and the voltage drop in each of the two feeder conductors supplying the circuit.

PER CENT VOLTAGE DROP.

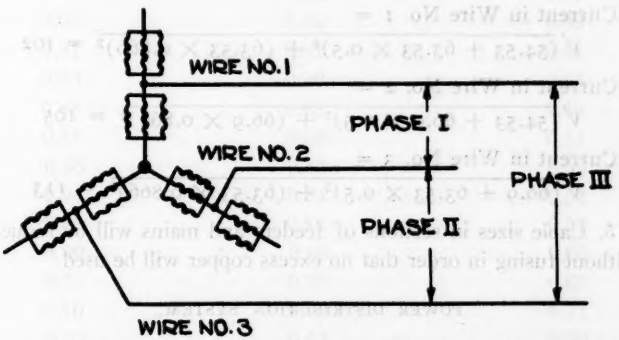
3. Per cent (%) voltage drop =

$$\frac{10.8 \times \text{Load, including allow. for spares} \times \text{Double Length} \times 100}{\text{Size cable in centimeters} \times 115}$$

4. On three-phase (3-wire) feeders, the current and the voltage drop is determined for each conductor.

(a) The lighting circuits are based on unity power factor, and inductive losses and skin effect are considered negligible, therefore no allowance is made for them. The single phase loads are connected on the 3-phase feeder as follows:

Phase I connected to wires Nos. 1 and 2.
Phase II connected to wires Nos. 2 and 3.
Phase III connected to wires Nos. 1 and 3.



(b) The resultant current in each of the feeder conductors is then the vector sum of the connected loads on each of the phases connected to that conductor, or

Wire No. 1 (resultant current) = vector sum current phases I and III.

Wire No. 2 (resultant current) = vector sum currents phases I and II.

Wire No. 3 (resultant current) = vector sum currents phases II and III.

(c) Based on the foregoing, the resultant current in each of the feeder conductors may be calculated as follows:

Wire No. 1 = resultant current =

$$\sqrt{(I_1 + I_3 \cos 60°)^2 + (I_3 \sin 60°)^2}$$

Wire No. 2 = resultant current =

$$\sqrt{(I_1 + I_2 \cos 60°)^2 + (I_2 \sin 60°)^2}$$

Wire No. 3 = resultant current =

$$\sqrt{(I_2 + I_3 \cos 60°)^2 + (I_3 \sin 60°)^2}$$

Example:

The load on phase I (connected to wires Nos. 1 and 2) is 54.33 amperes, the load on phase II (connected to wires Nos. 2 and 3) is 63.53 amperes, and the load on phase III (connected to wires Nos. 1 and 3) is 66.9 amperes. The current flowing in wires Nos. 1, 2, and 3 will be as follows:

Current in Wire No. 1 =

$$\sqrt{(54.53 + 63.53 \times 0.5)^2 + (63.53 \times 0.866)^2} = 102$$

Current in Wire No. 2 =

$$\sqrt{(54.53 + 66.9 \times 0.5)^2 + (66.9 \times 0.866)^2} = 105$$

Current in Wire No. 3 =

$$\sqrt{(66.9 + 63.53 \times 0.5)^2 + (63.53 \times 0.866)^2} = 113$$

5. Cable sizes in sections of feeders and mains will be reduced without fusing in order that no excess copper will be used.

POWER DISTRIBUTION SYSTEM.

Three Phase, 230 Volts A. C. Power Feeders and Mains.

1. *The resultant connected full load amperes* of a feeder shall be the vector sum of the currents (from the nameplates) of the individual motors or other power appliances connected to the feeder plus an allowance for each spare switch installed on the distribution panel. The allowance for each spare switch shall be *50 per cent of its rating at a power factor of 85 per cent.*

2. The vector sum (resultant current) of the loads on the feeder may be calculated as follows:

Resultant current (vector sum) = $\sqrt{(I_R)^2 + (I_X)^2}$ where I_R (current in phase with resistance) = sum of individual load resistance components, and I_X (current in phase with reactance) = sum of individual load reactive components.

3. The following table may be used in determining the resistance and reactive components of the individual loads:

Cosine or Power Factor (P. F.)	Cosine or Resistance Factor	Line or Reactive Factor
1.0	1.0	0.00
0.99	0.99	0.14
0.98	0.98	0.20
0.97	0.97	0.24
0.96	0.96	0.28
0.95	0.95	0.31
0.94	0.94	0.34
0.93	0.93	0.37
0.92	0.92	0.39
0.91	0.91	0.41
0.90	0.90	0.44
0.88	0.88	0.48
0.86	0.86	0.51
0.85	0.85	0.53
0.84	0.84	0.54
0.82	0.82	0.57
0.80	0.80	0.60
0.75	0.75	0.66
0.70	0.70	0.71
0.65	0.65	0.76
0.60	0.60	0.80
0.55	0.55	0.84
0.50	0.50	0.87
0.45	0.45	0.89
0.40	0.40	0.92

4. The line amperes of each motor or other power appliance and spare switch at its power factor is multiplied by the resistance (cosine) and reactive (sine) factors to obtain the Resistance Com-

ponent (I_R) and the Reactive Component (I_X) of each such load. The individual load components are then added arithmetically to obtain the components of the total load on the feeder.

Example:

All connected motors other power appliances and spare switches	Nameplate Normal Full Load		Cosine or Resistance Factor	Resistance component I_R	Sine or reactive factor	Reactive component I_X
	Line amps.	Power Factor				
Motor	7	.81	.81	5.67	.58	4.06
Motor	16	.88	.88	14.10	.48	7.68
Other Power Appliance	10	1.00	1.00	10.00	.00	0.00
Spare Switch (30 Amperes)	15	.85	.85	12.75	.53	7.95
			Totals	42.52		19.69

$$I \text{ (resultant current)} = \sqrt{(42.52)^2 + (19.69)^2} = 47$$

5. *The power factor of the load on the feeder* shall be the ratio of the current in phase with resistance (I_R) to the resultant current or $\frac{I_R}{I}$

From example above:

$$\text{Power factor of feeder} = \frac{I_R}{I} = \frac{42.52}{47} = 0.905$$

6. *The resultant maximum load amperes* on a feeder shall be considered as the vector sum of the starting amperes of the motor having the highest starting current and the normal full load amperes of all remaining motors or other power appliances and allowance for spare switches.

7. *Feeder cables* shall be of a centimeter size in accordance with table for Navy cable ratings and will carry itermittently the *resultant maximum load amperes* (as defined in paragraph 6), and shall in no case be of a size less than required by the tables to carry continuously the *resultant connected full load amperes* (as defined in paragraph 1); also the centimeter size shall be such that the maximum allowable drop, based on *the resultant connected full*

load amperes shall not be exceeded. However, consideration shall be given to the selection of a smaller size cable where the "operating load factor" involves consideration, such as intermittent duty which warrant a smaller size.

8. *Main cables* feeding individual motors (or other power appliances) shall be of centimeter size not less than that required to carry intermittently 150 per cent of the normal full load line current of such load. Sizes for mains as regards voltage drop shall be determined in the same manner as for feeders, except that no "Drop Factor" shall be considered.

9. *The Drop Factor* may be defined as the factor by which the drop by direct current must be multiplied in order to obtain the drop produced by an alternating current of the same value. The drop factor is a function of the ratio between the reactance volts and resistance volts, the power factor, and the percentage value of the resistance volts. The first component, ratio between the reactance volts and resistance volts, depends upon the size of wire, spacing and frequency; while the second component, the power factor, is entirely a function of the load. The third component has very little effect on the "drop factor" and for practical problems may be neglected.

10. *The Drop Factor* to be applied in calculating the voltage drop may be calculated from tables I and II. The values in table II have been taken from a table in an article published in the April, 1907, number of the "Electric Journal" by Charles F. Scott and Clarence P. Fowler.

(a) *The ratio of reactance volts to resistance volts at 60 cycles* for 3 conductor cables (assumed for distance between wires as installed in conduit), for the size cable used is given in the table below:

TABLE I.

Ratios of Reactance Volts to Resistance Volts at 60 Cycles.

C. M. Size of Cable	Ratio
16,380	0.05
20,740	0.08
26,240	0.12
33,120	0.14

C. M. Size of Cable	Ratio
41,620	0.15
52,440	0.22
66,560	0.26
83,500	0.32
105,600	0.38
133,100	0.54
167,800	0.64
211,600	0.76
300,000	1.01
400,000	1.49

(b) The ratio (specified as above) for the power factor of the feeder load determines a drop factor which is taken from the following table:

DROP FACTORS

Ratio of reactance to resistance.	Drop factors for feeder power factors of							
	1.00	0.95	0.90	0.85	0.80	0.70	0.60	0.40
0.1	1.00	1.00	1.00	0.94	0.88	0.80	0.70	0.60
0.2	1.00	1.01	1.01	0.98	0.92	0.86	0.82	0.67
0.3	1.00	1.05	1.05	1.02	0.99	0.93	0.89	0.74
0.4	1.00	1.08	1.10	1.08	1.04	1.00	0.93	0.82
0.5	1.00	1.11	1.14	1.13	1.10	1.07	1.01	0.92
0.6	1.01	1.15	1.18	1.19	1.15	1.14	1.09	1.01
0.7	1.02	1.18	1.23	1.24	1.21	1.20	1.17	1.11
0.8	1.02	1.21	1.28	1.29	1.28	1.27	1.24	1.20
0.9	1.03	1.25	1.33	1.34	1.34	1.35	1.32	1.29
1.0	1.04	1.28	1.37	1.39	1.40	1.41	1.39	1.38
1.1	1.05	1.32	1.41	1.44	1.45	1.48	1.47	1.46
1.2	1.06	1.35	1.46	1.50	1.51	1.55	1.54	1.55
1.3	1.07	1.39	1.51	1.55	1.57	1.62	1.63	1.64
1.4	1.08	1.43	1.55	1.61	1.64	1.70	1.71	1.72
1.5	1.10	1.47	1.60	1.67	1.70	1.77	1.80	1.81

11. Voltage Drop Calculation

Per cent (%) voltage drop =

$$\frac{10.8 \times 1.73 \times \left\{ \begin{matrix} \text{Resultant Full} \\ \text{Connected Load amps.} \end{matrix} \right\} \times \text{Single Length} \times 100}{\text{Size of Cable in centimeters} \times 230} \times \text{Drop Factor.}$$

12. The total per cent (%) drop from the motor or appliance to the switchboard is the sum of per cent drops on the main and on the feeders.

A SPECIAL FUEL OIL RELIEF VALVE.

By C. J. Odend'hal, Commander (E), U. S. C. G., Member.

There has recently been developed a special relief valve equipped with a spring compensator which has performed so satisfactorily in service that it is believed a description of its design and operation would be a matter of interest. The principal feature of the design is the compensating mechanism interposed between the sliding plug (23) Figure 1, and spring plate (17). The mechanism consists of three links (20) spaced 120 degrees around the vertical spindle (14) and pivoted at (21) to the link bracket (22). The end of each link is equipped with a hardened lower roller (19) riding on sliding plug (23) and a similar roller (18) bearing on spring plate (17). The horizontal distance between the fixed center (21) and center of lower roller (19) remains practically constant while the horizontal distance between the fixed center and center of upper roller (18) decreases as the valve opens. The ratio of the horizontal distances increases with the lift of the valve disc. As the spring tension also increases the correct proportion of the two insures a close regulation of pressure throughout the stroke of the valve disc. The mechanism is readily accessible for inspection, cleaning and repairs as shown on Figure 1.

The screw spindle permits adjustment of the pressure from 15 pounds to 600 pounds and the valve operates freely at all pressures within this range without chattering. The gland nut can be set up as tightly as desired to eliminate all leaks without affecting in any way the operation of the valve. The performance therefore is independent of any outside influence, and is affected only by internal conditions which are practically constant over the entire range of operation. Wear is reduced to a minimum, upkeep is negligible, and the life of the valve is the life of the vessel. The valve is particularly recommended as a by-pass valve in the fuel oil burner line and on lubricating oil systems where constant pressure is desired.

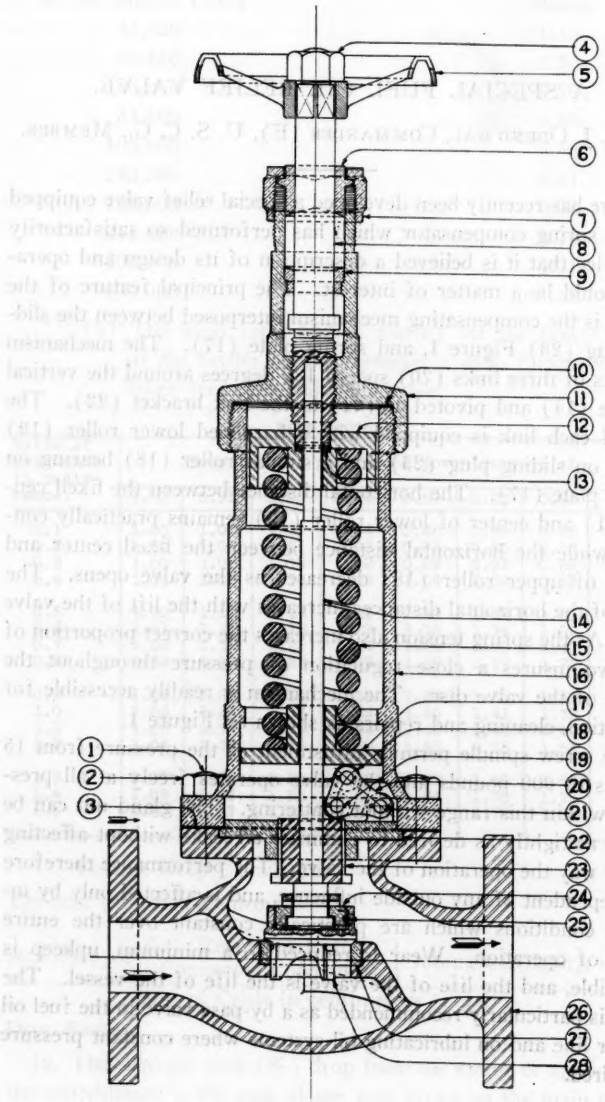


FIGURE 1.

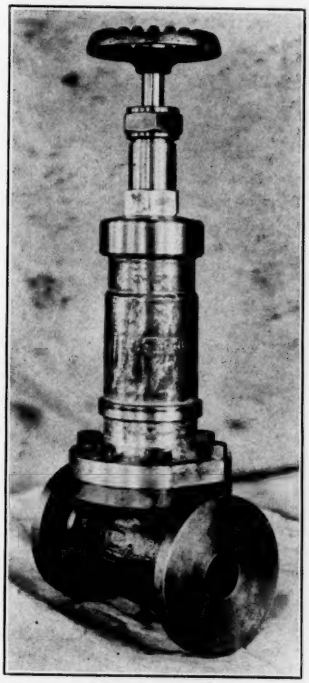


FIGURE 2.

Valves of this type (Figure 2) were purchased and one installed per vessel between the fuel oil discharge line to heaters and the fuel oil suction manifold by passing fuel oil above the amount necessary to maintain a desired pressure at the burners. Such an arrangement allowed the elimination of three ¾-inch conventional type valves which were fitted one to each pump. The latter valves caused a great deal of annoyance as they were not equipped with hand wheels, necessitating the use of a wrench for regulating the pressure, would not lift sufficiently to prevent the pressure increasing to an alarming extent, were extremely noisy, and were absolutely useless as pressure regulators. The compensated type, on the other hand, could be readily and conveniently set to any pressure, size for size. The compensated type would lift sufficiently to handle five times the volume of oil handled by the conventional type, and were quiet in operation. The replacement of the three ¾-inch valves by the one 1¼-inch special valve mentioned, permitted any and all pumps to be operated at all speeds with a valve lift commensurate with the requirements.

The following report was received from the Coast Guard Cutter *Mendota* covering the operation of the 1¼-inch special fuel oil valve installed in that vessel:

"In service the valve operates very smoothly and consistently, and is extremely sensitive to any movement of the adjusting handwheel. Under normal cruising conditions the variations in the fuel oil pressures when cutting in or out one or two burners are

TABLE I.

6 burners	5 burners	4 burners	3 burners	2 burners	1 burner	No burners
100	100	100	103	105	105	107
120	120	120	120	120	122	125
140	140	145	145	145	145	145
160	160	160	165	165	167	167
180	180	180	180	183	186	187
200	200	202	205	205	207	208
220	225	230	232	235	235	235
240	240	240	242	245	247	249
260	265	270	275	275	275	275
280	280	282	284	286	288	288
300	303	305	308	310	315	315

52-20 Sprayer plates were used up to 240 pounds gauge.
55-20 Sprayer plates were used from 240 to 300 pounds gauge.

so small as to be entirely negligible, and the operation of the valve, in general, is considered eminently satisfactory. A test was run on October 27, 1932, in order to ascertain the operation of the valve under extreme conditions, and the results are given on Table 1. In making these tests the turbine driven fuel oil service pump was used. It is quite likely that some of the variations observed were caused by restrictions in the discharge line from the relief valve to the oil suction manifold, as there are in this line a valve and a number of bends and 90-degree elbows."

As stated above, the valve was installed between the fuel oil discharge line to heaters and the fuel oil suction manifold. If the valve had been installed on the discharge side of the fuel oil heater better results would have been obtained, as the cold oil prevented a free movement of the compensating mechanism besides adding materially to the friction in the discharge line from the valve.

TABLE II.

Size of sprayer plate No. 5520 — Coast Guard Cutter *Champlain*
R.P.M. motor 1100 — Date 19 November, 1932

Original Gauge Setting	Gauge Readings—Shutting Off Burners.					
	6 burners	5 burners	4 burners	3 burners	2 burners	1 burner
100	100	105	100	100	100	100
125	130	127	127	125	125	125
150	155	155	153	150	150	150
175	180	180	180	175	175	175
200	200	203	203	205	205	200
225	230	230	227	227	225	225
250	255	255	253	252	250	250
275	285	280	280	277	275	275
300	310	310	305	305	300	300

Original Gauge Setting	Gauge Readings—Cutting in Burners.					
	1 burner	2 burners	3 burners	4 burners	5 burners	6 burners
300	300	295	295	285	290	290
275	275	275	275	272	272	270
250	250	250	250	248	250	250
225	225	225	225	223	223	220
200	200	200	200	195	195	200
175	175	175	175	170	170	170
150	150	150	150	145	145	145
125	125	125	125	125	123	122
100	100	100	100	100	100	100

Baume fuel oil in tank 14.5. Temperature of fuel oil pump section 75.

Upon opening an additional burner when using heavy fuel oil a period not exceeding 5 seconds is required for pressure to return to normal; whereas on account of restricted flow in the discharge line, about one minute elapses before restoration of normal pressure upon shutting off a burner.

A PRODUCER'S ANALYSIS OF THE CONTRIBUTIONS ON STEEL CASTINGS IN THE FEBRUARY, 1933, ISSUE OF THE A. S. N. E. JOURNAL.

By R. A. Bull.*

The writer appreciates the opportunity of discussing the practices and product of his industry, following his study of contributions in the February issue of this Journal. Comments made by a Navy engineer, a ship builder, and a steel founder, all prompted by what has been published recently by this Society, should be helpful to everyone concerned. It will be interesting, finally, to compare the views held in each of these fields of activity, in so far as the opinions may be regarded as representative.

The editor has given the present writer the privilege of extending his remarks beyond the limitation of comments on the previous contributions. In this as in other respects the Navy has shown no disposition to handicap itself or its supplying industries by awkward restrictions, such as have been self-imposed occasionally by some organizations.

DISCRIMINATION IN PROCUREMENT.

The editor remarked in his "Foreword" in the February number that the quantity of steel castings used by the Navy would be materially increased if sound castings could be assured. Following this, mention was made of the required purchasing procedure of the Navy, "which precludes the possibility of selecting its source of supply on any other basis than competitive bidding."

The latter comment in the preface to the specific discussions of the subject, prompt reflections of great practical significance. Probably the steel casting industry in the United States includes now approximately 275 foundries, having a total annual capacity exceeding two million net tons. These plants embrace those oper-

* Director, Electric Steel Founders' Research Group, Chicago, Ill.

ated as subordinate departments for the manufacture of parts put into completed assemblages in the parent works. Perhaps the number of steel foundries that are not related exclusively to other and more locally important enterprises is about 175. It is these casting plants that are wholly or partially in the "commercial" class in which the Navy is interested (apart from its own steel foundries).

Necessarily the manufacture of commercial steel castings is enormously diversified, as shown by very wide ranges affecting individual pieces, in weight, in over-all size, and in grade of metal selected for the casting. Naturally, in any such industry supplying in ordinary times as much as 30 per cent of its entire output for one general purpose, and smaller but considerable percentages of its output for each of several other purposes, there would be numerous plants particularly equipped for special classes of work. The specialized foundries that make railroad steel castings include the largest individual tonnage producers. But the great majority of steel foundries are in the jobbing class, although some of these have special equipment for devoting part of the output regularly to castings for particular purposes.

In these jobbing foundries there are very great differences in equipment and in personnel. Some of the plants confine their activities to the manufacture of plain carbon steel. Most of them now put a small proportion of the output into three or four grades of special steel. A few foundries make many varieties of steel the number of grades produced in individual plants in some cases amounting to as many as 30, within a single month. The sizes of plants vary considerably, even within the chosen general field of distribution of the product, as regulated largely by melting process and economical heat size.

Particularly under the industrial conditions that have recently prevailed in this industry (which produced probably not more than 10 per cent of its capacity in 1932) there is a vast difference in the degree of financial stability in these miscellaneous steel casting shops. But there has always been and probably there will always be a considerable difference in this important respect.

Supplementing all these factors that indicate the opposite of uniformity in the product, there are the vital elements of technical

alertness and honorable policy, either of which may exist without the other in the single concern. Unquestionably ethics play an important part in giving the customer what he expects to get. And it would be foolish to suggest that, on the average the men engaged in steel founding exhibit any better degree of honesty than do the same number of men in any other commercial undertaking.

It would be strange indeed if all these differences in equipment, supervisory control, technical ambition, financial standing, and inclination to deal squarely with the consumer, did not result in a rather wide range of prices for castings of any particular kind that may be produced in many of these plants. Everyone knows that, generally speaking, material that is made cheaply is sold cheaply; and that it costs money to surround manufacture with all safeguards necessary for the production of a thoroughly dependable product. Continued manufacture of such material can be expected only when the owners get a satisfactory return on the investment.

I am not a salesman. And these comments are not inspired by any lately developed complex resulting from the deplorably low prices of goods and commodities that have prevailed for some time. These matters are mentioned because the use of a great many of the steel castings applied to ship construction justifies the employment of superior foundry technique and the existence of other requisites mentioned, characterizing concerns that can be regarded as satisfactory sources of supply. Unquestionably, there was a logical basis for the Government regulation requiring orders to be placed on the basis of prices bid. It is not within the writer's province to advocate some feasible, specific modification of present regulations which would permit a safe and desirable degree of discrimination by the Navy, in considering quotations for steel castings. But in view of some criticisms made against the American steel casting industry, it is important to point out that the Navy can never reasonably expect to obtain thoroughly satisfactory castings invariably, until there is set up some procedure permitting discriminatory consideration of proposals, in other respects than price alone. It is unfortunate for the Government that it does not have available some such procedure as that employed by many

large transportation and industrial corporations, which have separately maintained approved lists of suppliers, from which potentially acceptable bids are restricted. It should be remembered that in any industry such as that producing steel castings, having a great many manufacturing units where the "personal equation" is involved to the extent that labor represents, roughly, 50 per cent of the total cost of production, it is highly imporant to be selective in procurement. And it may be remarked in passing that the Navy's problem in discriminating would be accentuated with any construction policy tending to increase proportionately the required number of steel castings of moderate rather than huge size, because of the resulting larger number of foundries soliciting orders for the material.

SURFACE WELDING—ITS CAUSES AND EFFECTS.

Captain Shane's comments are introduced with remarks concerning welding to make steel castings acceptable. The writer has been familiar with welding for salvaging purposes in the steel foundry for a long time, and recalls his use, progressively, of the blacksmith fire, thermit, water barrel rheostats, resistance grids, and acetylene generators, before causing a motor-generator set to be constructed a quarter century ago, for welding defects in steel castings.

This participation in early development is mentioned only to explain a familiarity with welding as done in steel foundries, with 14 of which the writer has been connected in a period of more than three decades. This experience results in the conviction that welding as done in the competently managed steel foundry has been confined very largely to improving the surface appearance, in ways that would be absolutely unnecessary for the proper functioning of the castings; also occasionally to an extent that might consistently be reduced, even for the sake of presentable appearance. That is a factor for which the average purchaser must apply a standard peculiarly his own. It may be based on an improper understanding of feasible approaches to perfection, in casting production. Very thick castings, while poured when possible from steel appreciably lower in temperature than required for thin castings, are apt to have more surface blemishes than the

latter have. This is partly because heat attack on the mold surface is regulated considerably by the period of time of contact with the hot metal.

Insistence of the purchaser on a very smooth appearance, despite the inherent difficulties of skillful production, occasionally may have prompted the wholesale welding of surface blemishes to a degree and in ways that cause this operation to weaken the piece. The adhering deposit of weld metal should be prepared for by providing a reasonable depth of cavity to hold it, and by removing all non-metallic matter from the hole. But the workman should make the clean cavity no deeper than necessary to place new metal firmly in position. Where surface welding is done in wholesale fashion, some defective spots may be welded in ways prejudicial to behavior in service. Obviously, the remedy for excessive welding for the sake of appearance, preferably is to be found in more effective prevention of these small surface defects; and secondarily, in the shipping of the casting with a slightly marred exterior.

What is an objectionable surface condition? If it were possible to give an answer in words, the description would vary, depending on the kind of casting involved. It would seem that sometimes the effect of surface blemishes on the performance of steel castings has been subordinated injudiciously to the aesthetic element of presentability. It is logical to suspect that it would retard the further development of steel molding practice and the attainment of the highest physical properties to do a lot of welding regularly on steel castings, particularly those of moderate and large proportions, for obliterating surface blemishes of very small size, of a nature indicating no probability of extension of the defect under stress, or of hurtful effect otherwise. One should differentiate somewhat, as to the advisable extent of welding for presentability, because generally the ultimate consumer's preference for smooth surfaces increases as the size of the casting decreases, for understandable reasons. This circumstance, introducing an important commercial factor, would be apt to make the small steel casting maker more "appearance-conscious" than the producer of many large castings. The economic sense of proportion should be technically applied with an appreciation of the nature of the job undertaken by the producer.

These remarks are intended as general comments for rather wide application, and have significance for the Navy, only if and to the extent that its policy might have placed this department of the Government in the category of some industries that stress smooth appearance to an extent that is commercially unattainable as yet in America, except through considerable surface welding.

EXTERNAL AND INTERNAL INDICATIONS OF SUITABILITY.

The consideration of such questions naturally leads to the discussion of molding sand practice. Captain Shane found that much of the testing equipment for sand control in Europe was purchased in this country. This was to be expected because systematic molding sand research was jointly undertaken in America in 1921, several years before much cooperative work of this character was done abroad. The writer had the task of heading the joint committee on molding sand research for the first three years of its existence. During this period of great activity in developing test methods for ascertaining properties of sand mixtures, ten members of this large committee of 60 individuals were directly connected with steel foundries. This shows the extent to which the steel casting industry in America has been disposed to pioneer and to cooperate for the improvement of the product, in one very vital matter.

It would seem that in the United States we labor under a handicap from the standpoint of natural sands adaptable for steel molding. But within the last 15 years, as has been stated by many who have purchased the product of the steel foundry during that period of time, there has been a very great improvement in the surface appearance of steel castings in this country. Nevertheless, much remains to be done.

It is relevant to go somewhat into detail regarding the important relationship of sand control (affecting appearance and influencing welding) to the final degasification practice for the manufacture of steel castings. Captain Shane's references to additions of aluminum as made in Europe are very interesting. It is this element that is chiefly in mind when the writer speaks of final degasification. (This word is more suitable than deoxidation, because oxygen is not the only gas involved.) It may be

that numerous foreign steel founders place more significance on surface appearance and less significance on the physical characteristics of the metal, than do American producers. There is some evidence supporting such a surmise. Certainly the requirements for ductility in specifications for cast steel as widely used over-seas, considered collectively, are less impressive than those in specifications for steel castings as adopted by the U. S. Navy, the U. S. Army, the American Society for Testing Materials, and by numerous large consumers of steel castings in this country. For example, in four separate specifications for steel castings developed by the British Engineering Standards Association (latterly re-named the British Standards Institution), there is no requirement for reduction of area, or for yield point, proportional limit, or "elastic limit" (so-called). Most metallurgists now agree that reduction of area is a better index to the ductility of steel than is elongation. A fair average of the British standard specifications mentioned for carbon steel castings presents the combination of minimum values of 26 tons for tensile strength and 20 per cent for elongation in 2 inches. Cold bend tests are called for in two of the four specifications, and must meet the requirement of 120 degrees for the soft grades.* Contrast these figures with the last specification for carbon steel castings adopted by the American Society for Testing Materials (established as a standard in 1929). This calls for not less than 70,000 pound tensile strength, 36,000 pound yield point, 22 per cent elongation in 2 inches, and 30 per cent reduction of area, for the grade of soft carbon cast steel used for most industrial and railroad purposes in this country.*

Now this brings us back to the consideration of aluminum, because of its injurious influence on ductility. The connection between aluminum additions and surface appearance would be obscure to the average consumer without elaboration. If the American steel foundryman should place less significance than he does on solidity and ductility in his product he could resort to practices in making the metal and the mold which probably would result in a better average appearance of the casting; consequently

* Note: Summarized data on physical and chemical requirements in these and many other specifications may be found in "Purchase Requirements for Steel Castings," by R. A. Bull, Symposium on Steel Castings, A.S.T.M.-A.F.A. (1932), pg. 39-75.

providing superficial evidence of a product superior to that now manufactured. But the result could readily be a material falling off in homogeneity, ductility, or shock resistance; or in all of these characteristics. A condition of slight interior sponginess could be brought about by the introduction into the molding sand of excessive amounts of certain materials that would, because of their volatile nature, form a gaseous blanket of protection, preventing close contact of the molten metal with the sand, and thus reducing the liability of partial fusion of the sand face, and of detachment of particles from the latter. These particles often are transformed into a slag-like matter localized on the surface of the casting, and are the occasion for much surface welding in some American shops.

The volatile materials that have a beneficent effect as to surface appearance are very apt, if used in large proportions, to have a harmful influence in developing porosity (a word that is often discarded in the foundry in favor of the term "pin holes"). An interesting characteristic of these pin holes (which may be due to poorly degasified metal as tapped but are probably much more often due to mold conditions) lies in the fact that they are reluctant to show themselves, and frequently are not apparent at all in the casting as removed from the mold. Generally they are exposed in some degree, and occasionally in great degree, when a heavy annealing scale has been formed and subsequently removed. But they may exist in the interior of the casting and be hidden from observation after tumbling or blasting has been effectively performed to remove the oxide formed during heat treatment.

What has just been said in connection with aluminum practice relates particularly to green sand castings. For their manufacture special precautions must be taken for the invariable prevention of porosity. And thus far, despite prolonged investigations in many plants, there has been found no element or compound that is as effective in preventing pin holes as is aluminum. The green sand mold necessarily contains substances including water that are volatilized when the liquid steel enters the mold. Even during the transfer of the metal from furnace to mold, there is opportunity for oxygen to be absorbed by the steel, in degree

depending on the nature of the transfer. If we could move the metal from the furnace bath directly to the mold without appreciable air-contact, and if it were feasible commercially always to employ a thoroughly dry, oven-baked mold throughout, there would be no need for a final dose of aluminum, and no resulting impairment of ductility. But the shrinkage characteristics of steel are so great as to require, for the economical production of many kinds of steel castings, molds that are readily compressible, either through the absence of baked sand or through relatively expensive molds which may be described as veneered, with a baked face and an unbaked backing. An expedient that is useful in some cases is the ceration of large mold cavities, to permit movement caused by contraction of the casting. In making many castings, dependent on the design, the foundryman must provide either for compressibility or collapsibility of the mold, if he would succeed commercially in preventing so-called shrinkage cracks or hot tears (which may result from other causes than mold resistance).

It is apropos to state that there is nothing to indicate the belief among progressive American steel foundrymen that the physical requirements as established in this country for several years should remain as they are indefinitely. On the contrary, there is considerable activity indicating the probability of increasing the combination of physical requirements for some classes of carbon steel castings. Recently revised specifications of some important railroads, ordinarily heavy buyers of steel castings, are significant in this respect. The sentiment in this direction is not confined to consumers.

There is further evidence of the progressive spirit of American steel founders in specifications for eight grades of alloy steel castings for structural purposes, which have been extensively discussed in the related committees of the American Society for Testing Materials, and which, according to present indications, will be advocated by the Committee on Steel of the A.S.T.M. for adoption as a tentative standard, at the June, 1933, convention of the Testing Society. If and when these new specifications as now contemplated are issued, the Testing Society will have in effect as standards or as tentative standards, purchase requirements for

three varieties of carbon steel for castings (identified by tensile properties); one variety of high alloy steel (Austenitic manganese); and eight other varieties of alloy steel, the latter being for structural purposes, and distinguishable by physical properties and heat treatment specified.

In the light of these purchase requirements for 12 varieties of steel which stress physical tests above other considerations, one must conclude, after scrutinizing foreign specifications for steel castings, that the American manufacturer has taken the lead in cooperating with the consumer to develop purchase requirements that emphasize the quality of the metal.

MELTING SPEED, METAL TEMPERATURE, RISERS, ETC.

Captain Shane mentions statements made to him abroad to the effect that good steel can be made only by giving proper time to the melting and conditioning of the metal, and suggesting that there is too much "hurry-up" in America. Probably there is some basis for this, under conditions of average or heavy production. It may be that when there is a strong pressure on the melting department for delivery of metal to the molding floor, there is too often a yielding to the demand for speed, with a resulting harmful effect on the qualtiy of the metal. Depending on the shop conditions at the moment, it takes a strong-minded general superintendent or works manager always to adhere to the policy of moderate speed in producing the metal. It is not likely that any experienced, conscientious steel foundryman will deny that excessive speed in finishing a heat of steel in the open-hearth or in the arc furnace is apt to lower the quality of the metal.

There would be wide endorsement of the opinion reached by Captain Shane that it is desirable not to pour castings at a temperature above that required for the particular job. Experience in eliminating all possible causes for shrinkage difficulties and tendencies of the sand to "burn-in" on the casting shows the desirability of pouring at a temperature merely hot enough to completely fill all mold cavities, with proper delineation of details.

Captain Shane observed with surprised (without subsequently expressing approval or disapproval in his published report) a French foundry's practice of pouring water on the tops of risers immediately after withdrawal of the ladle. The explanation by

the foundryman was that all the feeding necessary had already occurred. Captain Shane remarks that at Anacostia it has been found that it takes only a few seconds for steel castings to "set."

There may be different interpretations of the word "set," as here used. There would be no argument aganist the contention that there is an immediate freezing of the skin of metal after the steel in the mold stops flowing, and that there follows a progressive contraction of the casting; also that, depending largely on cross-sections involved, there is an appreciable period in which steel in the interiors of members remains at a temperature calling for a reservoir to fill voids created. It seems doubtful to the writer that any steelfoundryman could argue convincingly before his experienced colleagues for a sudden, crude chilling of a sink-head designed to do a needful thing "to the last drop." Throwing cold water on a red-hot riser (without opportunity for regulating any part of the procedure, as when liquid quenching during heat treatment) is apt to create undesirable conditions in the casting proper, depending on riser-height and other circumstances. Certainly it is the logical judgment of most American foundrymen that one needs to retard rather than to accelerate solidification of riser-metal, for getting the maximum benefit from the minimum amount of steel in the head. And it is quite possible that the most competent steel founders in Europe would condemn the practice in the French foundry mentioned. There must be considerable differences in the product over-seas as in America.

The use of chills, and in contrast, of very heavy and numerous risers, has been spoken of in connection with the inspection of foundries abroad. The meticulous examination of castings intentionally machined destructively for the detailed examination of all critical members has disclosed the fact that frequently external chills and sometimes internal chills of proper kinds may be used economically and satisfactorily in respect to the behavior of the piece in service, in preference to an excessive weight of metal in risers. The place to start, for the elimination of chills to the greatest practicable extent, is on the drawing board. Unquestionably chills are effective at times when the design of the casting is such that a perfectly solid condition of a portion of the piece cannot result from pouring the mold in any position that will permit ade-

quate feeding to compensate for contraction. This is a fact that should be emphasized for the better understanding of designing engineers. They are apt occasionally to send a job to the foundry which has very objectionable characteristics of design, necessitating manufacturing expedients that are expensive for seller and for buyer and which are inadvisable to employ in the case of a well designed casting desired to have all of the resistance potentionally existing in the material. Occasionally such devices, when unskillfully used, prejudice buyers against them unqualifiedly. Captain Shane's comments regarding the cooperation that exists in some sections of Europe are relevant to this point. He mentions the preliminary examination of the drawings by the foundry executives, and the prevailing procedure in Europe to depend on the foundries to make the patterns. Certainly these are most commendable practices, and would do much, if universally applied in this country, to improve the quality of many steel castings, and to reduce the first cost (and sometimes the ultimate cost) to the buyer.

Captain Shane mentions a foundry visited in Europe where patterns are not employed but are replaced by core boxes. It is stated that this entire foundry is laid out for mass production. This is an interesting method of molding which has been employed for many years successfully in the United States for certain types of large steel castings, with which the writer happens to be very familiar. But the method is not adaptable economically for most steel castings, particularly those made in miscellaneous shops where material for the Navy is produced.

The practice of putting vent holes in ladle shells was observed over-seas. This is a very common procedure in this country. Undoubtedly, the practice is advisable to permit the escape of steam generated from the moisture in the ladle lining. It is rather surprising to learn that there were no teapot ladles seen in the inspection abroad. Such vessels are fairly common in American foundries making small steel castings, although opinions of competent producers differ as to the advantages of such ladles as compared with lip ladles.

The writer believes that most steel foundrymen will cordially support Captain Shane's opinion that the pickling of steel castings

for most purposes is very undesirable. This practice is required by some American consumers. Painstaking researches made by competent metallurgists in this country show that there is an important relationship between the deterioration that comes from corrosion and that which comes from mechanical stress.

COMPARISONS OF FOREIGN AND DOMESTIC PRODUCTS.

The conclusion of Captain Shane's article leads one to infer that he has been more favorably impressed on the whole by the practices and products of foreign steel casting plants, as compared with the procedure and output of the industry in America. The present writer has pointed out what he believes to be more emphasis given in this country to the vital element of sand control and to the all-important element of the quality of the metal, as compared with the stress that has been placed on these matters over-seas. Mention has been made regarding some factors that might easily cause the casual visitor to form a highly favorable opinion of the product. I refer to the matter of surface appearance, frequently obtainable at some expense to solidity or ductility, depending on the consideration given certain constituents in the molding sand (natural or synthetic). An admirable natural sand may be an important element in favorably impressing the visitor. Generally speaking, it is true that more time is given to the average task involving manual labor abroad than in the United States. Probably this is another factor that influences appearance. It may also affect serviceability. No doubt in several industries we suffer somewhat in quality as the result of speed of production. It would be difficult at times to determine whether economic considerations for every one concerned (including profitable encouragement to the manufacturer) justify some sacrifice of quality to attain rapid production. We can only apply our sense of proportion. Any such question would be impossible of settling without such a comprehensive examination of the product abroad as no American visitor can make within a few months. One cannot judge merely by the appearance of the product—a truism with which Captain Shane would quickly agree. One may get a fair idea of its probable nature by closely noting the details of practice, following experience enabling the observer to understand the significance of all major details of steel foundry technique.

It is hoped that Captain Shane's report will be read widely by American steel founders, because it contains many usefully suggestive observations, and should stimulate a spirit for better achievement, without which this industry could not measure up to its enormous possibilities. It may be optimistic to expect that the great majority of American steel founders will be actuated constantly by the ambition to improve the quality of their product. But constructive criticisms from intelligent, fair-minded persons representing consumers (such as Captain Shane and his associates in the Navy Department) will help materially to stimulate the competent and conscientious producers, and should prompt other manufacturers who turn out an indifferent product to do their part in striving to establish the steel casting industry of America firmly in a position of internationally recognized leadership.

NEED FOR MORE SCIENTIFIC DATA.

Commander Almy's introductory to the discussion of factors deserving consideration at the Naval Research Laboratory, announces the purpose of determining fundamental factors, to permit the more scientific manufacture of steel castings. Probably some steel foundrymen would reluctantly admit the correctness of the Commander's declaration that their industry is woefully lacking in scientific control of the elements involved in manufacture. But there is justification for this statement, although its truth does not, *ipso facto,* convict the steel foundryman of indifference toward the acquisition or application of scientific data. No one who has constantly attempted to learn more of these facts to be used as a basis for regular practice would deny that there are yet many variables, some extremely difficult to identify, and possibly more difficult to control. The present obscurity surrounding these factors presents a complex problem. This fully justifies such efforts as are exerted at Anacostia, by those who need the product of the steel foundry made by a technique as nearly perfect as can be commercially maintained. This being so, progressive steel foundrymen are gratified at the inauguration of the Navy's investigation.

THE QUEBEC BRIDGE DISASTER.

Dr. Canfield has briefly outlined the research program in progress at the laboratory. His introduction consists of comments

regarding the disaster to the Quebec bridge, occasioned (perhaps) by the breaking of a steel casting. Some details of the report regarding the failure, after painstaking examination of what was available for investigation, have considerable significance when one speculates about the condition of the casting. Dr. Canfield remarks that final erection occurred in 1917, and "followed generally the same scheme as originally planned with the exception that the cast steel shoes were replaced by articles assembled from forged steel and rolled sections. It was perfectly successful."

In this connection a few statements here quoted from an official report are significant: "Whatever caused the failure of the casting, it was interesting to note that the casting had been subjected to weight of the span and span erecting equipment during erection, and carried its proportion of the span load until it failed. The total load of span and erecting equipment was 10 per cent in excess of the normal load it had to carry, for purposes for which it was designed. The bearings for the second span were redesigned and steel castings eliminated for drop forgings." The load of the span had been carried successfully by the casting for about eight weeks. No one can say whether the substituted wrought material would have failed if the friction plate bearing finally used had been chosen originally, instead of the universal joint type of bearing employed in the use of several steel castings. The casting in question, which may have ruptured, was not mechanically attached to the base casting, but merely rested on a roller bearing. In the opinion of some engineers this casting placed above the roller may have become dislodged without breaking. In view of all the facts that are likely ever to be known, there is no justification for an assumption casting reflection on the Canadian foundry that made the casting, or on the steel casting industry in America, in connection with the Quebec bridge disaster.*

PRE-DETERMINATION OF CASTING-SOUNDNESS.

The outline of the investigation at the Naval Research Laboratory contains a statement that appears to me to justify considera-

* Note: The writer desires to explain that he has never been associated with the company that supplied the Quebec bridge casting here discussed. Consequently particular interest in this matter, taken by the writer, is due solely to his connection with the producing industry in America.

tion by anyone who has a clear understanding of what has been accomplished when a good steel casting is made. I quote the sentence in mind, found in Dr. Canfield's contribution: "If steel casting technology had arrived at a stage comparable with other metallurgical arts, the foundryman would know in advance that his casting would be entirely sound." I venture the assertion that a complete understanding of all the complex details of steel foundry technique, coupled with comparable familiarity with modern methods of manufacture of many wrought metal parts, would result in the definite conviction that, with a given degree of effective supervision, a given degree of craftsmanship, and a given degree of modernization of suitable plant equipment, the very nature of required operations for the manufacture of miscellaneous steel castings is such as materially to increase the probability factor relating to imperfections in the product.

The above statement should not be considered carelessly and construed to mean that one is likely to find objectionable defects in the average steel casting. The present writer has mentioned as one basis for the comparison, the same degree of competent supervision. That immediately involves the consideration of *what is supervised.*

It should not be forgotten that in the steel foundry where miscellaneous castings are produced, there is a very large element in human labor, necessitating supervision of workmen to an extent that is very unlike that where, for example, steel rails, plates, I-beams, etc., are rolled; and where drop forgings are made. The experienced steel foundryman has learned many important lessons needed for the successful choice of methods for any given type of casting, such as location and size of gate, position and dimensions of risers, sand characteristics of mold and of cores, employment of gaggers, chaplets, core rods and arbors, chills, nails, etc. But where jobbing castings are made, the superintendent daily has (during periods of normal production) a great many designs of castings to produce, which differ in some important dimensional characteristics from any thing previously made in the shop. Very often the small number of pieces and the delivery required prevent any such preliminary practice as is customary when several hundred or thousand pieces from one design are ordered. In the

latter case, time can be taken to make sample castings, and after their careful examination do any needed experimenting, as relocating gate, risers, etc. But for the very great majority of miscellaneous castings, the shop-men have to depend on their experience with jobs somewhat similar to those in hand.

Certainly, judicious sand control, proper furnace manipulation, and other procedures of kinds applicable irrespective of the design of the casting are extremely helpful. The foundryman realizes that the fluidity of the steel, largely determined by its temperature, is a factor that influences the ultimate condition of the casting to some extent. But the jobbing foundryman usually has, despite his efforts to segregate the molds, a large variety of cross-sections in the castings to be poured in each heat. Furthermore, in many castings one finds thick members that would be made best by metal poured "on the cold side," while other members that are thin require very hot steel.

Briefly, experience in running a jobbing steel foundry would quickly dissipate any idea that it is readily adaptable to the satisfactory pre-determination of many details of technique which influence the result. The miscellaneous steel foundry will always be a practical laboratory for the daily attempted solution of new problems. Engineering ingenuity makes it so. One cannot standardize a method of manufacture except when the product, by a reasonable degree of duplication, permits the adoption of methods that can be usefully repeated.

DESIGN PROBLEMS REQUIRING STUDY.

Dr. Canfield has briefly mentioned some interesting features of design to be studied. Steel foundrymen should vigorously encourage the intention to attack such problems as the most effective degree of taper connecting thin and thick members, and the radius or the radii forming the fillet. Mr. Crown has contributed a brief but very suggestive discussion of the influence of design, thus supplementing a valuable contribution on the design of brass and bronze castings, presented in 1932 before the American Foundrymen's Association by L. H. Fawcett, of the Naval Gun Factory. The latter paper is mentioned because, whatever the metal used, there are numerous precautions always to be observed by the

casting designer.* They are founded on fundamentals and need to be emphasized vigorously. Naturally, the principles require application with due regard for the peculiar characteristics of any metal under consideration. Because of the relatively high degree of contraction in steel, resulting from low carbon content and from high pouring temperature (factors directly related to each other) the influence of a metallurgically poor design would naturally be more injurious proportionately, for the steel casting than for many other castings.

We know that the ideal casting would have absolutely uniform thickness of members, for metallurgically sound reasons. We also know that it is necessary for innumerable purposes that steel castings be made with cross-sectional inequalities, some of them being very pronounced. But for many applications there are compromises in design that could be developed without handicap in assembling. It becomes very desirable (particularly so, perhaps, for the Navy) to ascertain the extent to which resistance to severe stresses may reasonably be expected for each of several possible methods of connecting thin and thick members. A factor involved is that of weight of the piece. Captain Davis' contribution bears on this point, and rightly emphasizes that stability or stiffness, obtainable in large degree by weight alone, must not be sacrificed when designing steel castings with proper regard for minimum advisable weight. There is a happy medium to strike in these cases. And it should always be kept in mind that, irrespective of the kind of metal or whether the part is cast or wrought, the relatively small radius is a handicap to stress resistance. Moore and Kommers, in their excellent book, "The Fatigue of Metals," have thrown much light on this matter, as have other masters of metal research.

Given, for example, an 8-inch thickness required for one member, and a 3-inch thickness needed for another portion of the steel casting, 24 inches distant, with construction possibilities permitting either an abrupt change of thickness or a very gradual slope, what represents the maximum resistance to the stresses that may be

* Note: Among recent noteworthy papers on steel casting design are the following: "Notes on the Design of Steel Castings," by F. A. Lorenz, Jr., Symposium on Steel Castings, A.S.T.M.-A.F.A. (1932), pg. 20-34; and "Foundry Factors Affecting Steel Casting Design," by K. V. Wheeler, Transactions of A.F.A., Vol. XL (1932), pg. 125-152. Information on the subject may be found in "Steel Castings as Machine Parts," by R. A. Bull, in "Machine Design," Apr. 1931, pg. 36-39, and May, 1931, pg. 37-40.

imposed? Where and how shall we make the line on the drawing board, remembering that the element of stiffness is one not to be forgotten (in degree depending on the part)? For deciding such questions, considerable research having very practical aspects is necessary. The steel casting industry needs reliable data on such questions, and assistance by the Navy in developing the information will be greatly appreciated.

COOLING METHODS IN HEAT TREATMENT.

This matter of design is closely associated with results obtainable from heat treatment. And the writer is gratified at the forcefulness with which Mr. Strauss calls the Navy's attention to the possibilities of which a great many users of steel castings have taken advantage with entire satisfaction, in a form of heat treatment that includes normalizing. The required amount of stiffness for a part that may be stressed beyond its ability temporarily to spring out of line or to weave is of course indicated largely by the values for yield point and tensile strength found in the material. Long experience demonstrates the entire safety of proper air cooling, thereby increasing these properties, for the very great majority of many kinds of steel castings, including varieties comparable to those used by the Navy. This is not to say broadly that such material should be used in the condition developed merely by the normalizing operation. Auxiliary draw or tempering treatments are needed for many applications calling for a very high combination of resistance to tension, bending, fatigue, and shock.

Some steel foundrymen have developed procedures for liquid quenching with great success, and have supplied material treated in this manner and subsequently tempered, in the cases of large castings having unequal cross-sections, as well as small and moderate sized castings which are very often quenched in oil or in water to develop properties of outstanding character, in many grades of cast alloy steels.

For the reasons indicated, the research at Anacostia might with great profit be extended to cover the determination of what happens to the steel casting of a design supposedly presenting the maximum condition as to possible hazard, when it is permitted to cool unrestrictedly in the air from the customary normalizing tem-

perature; and what subsequently happens to the piece after it is properly tempered. The investigation might be further extended very usefully to ascertain the effects from liquid quenching.

TYPICAL PHYSICAL AND CHEMICAL PROPERTIES.

Mr. Briggs has enumerated several factors calling for inquiry at Anacostia. The attention these details merit is not to be gauged by the brief references now made collectively to them. Some of the following comments may be helpful, as bearing on Mr. Briggs' discussion.

The list of the average physical and chemical properties, said by Mr. Briggs to be obtained in this country for the usual run of castings, might perhaps be modified. Presumably the values given apply to the soft grade of carbon cast steel as customarily used for marine, miscellaneous, and railroad applications. Probably a large proportion of this material daily is produced to specifications calling for not less than 70,000 pound tensile strength, therefore averaging appreciably more (after normalizing) than the 72,000 pound figure given by Mr. Briggs; also showing lower ductility values, ordinarily, than 30 per cent elongation in 2 inches and 50 per cent reduction of area. Perhaps the average carbon content would be closer to 0.28 than 0.25 per cent. Within the last ten years there has been a tendency in the steel foundry to increase the contents of manganese and silicon. The present averages now might be close to 0.75 and 0.35 per cent, respectively. The phosphorus and sulphur contents necessarily are regulated mainly by the acid or the basic nature of the furnace lining. Mr. Briggs' figures would apply to acid steel, but in such practice the sulphur percentage probably averages close to 0.05 per cent (the current maximum limit for most castings being 0.06 per cent).

The customary drawing or tempering treatment in this country for carbon steel castings, also for medium manganese steel castings is somewhat higher, in the writer's opinion, than the scale of 900-1100 degrees F., mentioned by Mr. Briggs. Draw treatments around 1250 degrees are quite common.

It might be remarked that in the very large foundry mentioned (not by name), where no heat treatment whatsoever is given, the carbon content is carefully kept appreciably below the general

average of the industry, for soft carbon steel castings. Of course this is desirable to obtain required ductility in the material in the "as-cast" condition.

DESIGN AS REGULATING USE AND KIND OF CHILL.

More extended investigation into the use of chills may convince the investigators at Anacostia that restriction to horse shoe nails and wire coils or spirals would not meet all requirements for remedying difficulties of design. It may be true that improperly used chills have produced more trouble than benefit in the foundry. The contention is debatable and not subject to proof. Nevertheless, serious troubles have been caused by unskillful use of chills in steel castings. Because of metallurgically wrong designing, occasionally a chill considerably larger in cross-section than the horse shoe nail or customary spiral affords the best opportunity for developing the most satisfactory condition commercially obtainable. Admitting that chills, especially large ones, are a necessary evil, it is important for designers to realize the extent to which they may be able to make the employment of such devices less frequent.

JUDGMENT IN USING X-RAYS AND GAMMA RAYS.

The comments regarding radiography prompt brief reference to the present need for attaining skill in the interpretation of exographs and radiographs. Considerable dissection is essential for developing accuracy in regular diagnosis. These remarks are not intended to imply that interpretation by Navy diagnosticians suffer in comparison with deductions by other industrial users of gamma rays or X-rays. Such examination of pilot castings may contribute very usefully to the effective manufacture of castings of certain kinds, ordered in considerable quantities. In addition, the use of rays is justifiable where the expense of such examination may be disregarded, in view of the nature of the casting and its contemplated use.

EXISTING AND DESIRABLE PERSONNEL.

Regarding personnel, discussed briefly in Mr. Briggs' contribution, the present writer agrees that the steel foundry today needs technically trained men who know a great deal about theory. But

I disagree with the latter part of the dictum that we need men "who know a great deal more about theory and less about the mechanical application of molding." It may be that the issue taken is based on my incorrect interpretation of the language used, and that there is no disagreement in ideas. At any rate, I would emphasize my conception that the "mechanical application of molding" involves a great deal (and can consistently include casting design). Much more than mere craftsmanship is involved. That must exist, *plus* understanding of and adaptation to the phenomena that occur throughout the filling of the mold and the progressive solidification and cooling of the casting. Facts most important to acquire for the successful supervision of such work can be obtained only by the application of theory to much practice on the molding floor. The relationship is intimate, eventually making of the preferred type of steel foundry executive, an individual of composite qualifications. Metallurgy, mechanical engineering, and craftsmanship are inseparably connected, for the routine task of competently running a steel foundry that makes a considerable variety of metals and shapes for many purposes.

While not desiring to extend this contribution unnecessarily, I cannot refrain from expressing hearty agreement with much that has been said by Messrs. McKinney and Batty. Their long experience qualifies them as experts in shop practice. Further, they have inherently the cooperative attitude that characterizes progressive steel foundrymen, toward the consumer. Such technicians are not in a very small minority among American steel founders. They are thoroughly conversant with the vast differences that exist in the problems of the producer of specialties or merchant shapes, contrasted with the problems faced in the miscellaneous steel foundry. The latter unfortunately are subject, by the very circumstances of the business, to no such predeterminable, scientifically established regulations as may be provided where a standard product is regularly manufactured.

There is recalled a very interesting paper by Rear Admiral Rock, presented in 1931 before the Society of Naval Architects and Marine Engineers. This contribution contained many references to steel castings, although not restricted to the discussion of that material. The author strongly emphasized the necessity of

close cooperation between the steel foundryman and his supplier, and the vital factor of satisfactory design from the shop-man's standpoint. One would judge from reading the contribution mentioned that the idea back of the present research at Anacostia was strongly supported by Rear Admiral Rock, following an extended opportunity for evaluating the results of foundry practice, and for forming an intelligent opinion regarding personnel in American steel foundries. In the latter connection, it seems worthwhile to quote this statement from the paper: "The successful steel foundryman today is a good metallurgist and is qualified technically in all phases of steel manufacture." It is appreciated that this comment was not meant to place my associates in the steel casting industry, collectively, on a pedestal. The more experience we have in steel casting manufacture, the more we realize the extent of our ignorance in respect to this extremely complex operation of trying to make a thoroughly dependable and presentable product, of almost any conceivable shape or weight, from a more or less temperamental metal poured into a cavity formed largely from what would be called dirt by the average man on the street. It is suggested that, despite the indifference of what probably is a small minority of steel foundrymen regarding the high quality of material required by the Navy, its investigators might ultimately be inclined to concede to the majority of my colleagues in this large industry, a considerable degree of practical application of scientific knowledge, qualifying them technically without disparagement in contrast with manufacturers of other metal products.

COMMENT ON SOME POINTS RAISED IN THE DISCUSSION OF STEEL CASTINGS.

By J. E. BURKHARDT, MEMBER.*

Most of the authors of the papers on steel castings in the February issue of the JOURNAL are agreed upon the importance of the design of the casting itself. Captain Shane referred to it in the main paper and other writers expressed themselves in a way that might give the impression that if the design were proper there would be little trouble with steel castings.

About four years ago we started to develop this idea and our experience might be useful to others. It should be understood that what follows refers to the more important castings for marine work such as turbine casings, gear cases, valves, stern frames, shaft bossings, etc. Generally speaking, only very few of these castings are required of the same design; one, two or four being the rule.

Our early attempts at co-operation with the foundry were not at once successful. The rounded corners and large fillets, mentioned in one of the papers, are easily enough provided as is well known in every drawing room, but the other recommendations of the foundry representative such as " no thicknesses less than 1¼ inch," and " all parts of the same casting to be uniform thickness," though equally well known are hardly constructive suggestions because they are impossible of adoption.

Specific discussion regarding the general design of the casting, location of ribs, bosses, etc., in which some latitude was offered, brought little or no discussion and it was impossible to avoid the impression that the foundry people were unable readily to read the plan, and therefore to visualize the completed casting.

We overcame this by introducing the foreman patternmaker, who happens to be something of a foundryman, as liaison officer between foundry and drawing room to interpret and advise the designers as to what they should do, and to warn and prepare the

* Chief Engineer, Bethlehem Shipbuilding Corp., Ltd.

foundry for those parts of an important casting that would require special consideration.

Perhaps this would be one of the functions of the foundry engineer that Captain Shane refers to. We have had good success with this procedure and will continue it, but like everything else, it has its limitations.

For instance, before the design of the casting is completed the foundry to which it is going must be selected. This is not always possible. Foundry practices and opinions vary so widely that a design and pattern equipment worked out in co-operation with one foundry would have to be gone over again entirely for another foundry.

As an example of this, we are at the present moment having difficulty with a casting that, except for being a little larger and simpler, is very similar to a batch of 22 that we obtained from two foundries 15 years ago. At that time we had no rejections and not one of the whole batch was welded after leaving the foundry. I am sure of this because we had no welding equipment in the machine shop in those days. Incidentally, this experience does not speak well for progress in the art.

Some other practices mentioned in the articles we have found by experience to be beneficial.

Whenever the closest co-operation is not possible it is better to have the foundry make the pattern equipment.

Where eight or more castings are required off the same pattern, which is rare in the class of work under discussion, we order one extra casting to be made and delivered for rough machining. This casting may then be cut up and the information gained passed on to the foundry before molding on the rest is resumed.

Condemnations are so expensive to the user in lost machine work and delay, and to the foundry in cost of replacements, that there is nothing to be gained and much to be lost by neglecting any precautions in the foundry that will tend to ensure soundness in the casting.

I feel sure that users with experience in the type of casting to which I have referred are not likely to quibble about small differences in price if they felt that more liberality would be accompanied by fewer rejections.

More might be accomplished if foundries would specialize on types of castings, and those without experience curb their anxiety for work by refusing to undertake that for which they have no background of experience. In these days this practice is not alone a foundry fault.

While I can not say whether or not our foundries have what has been referred to as good scientific or engineering control, there can be little doubt about the good results that have been thus attained in other lines of endeavor.

Our principal difficulties are due to shrink cracks, cavities at intersections of walls, and porosity due to inclusions of sand or gases, and it would appear that the technique of molding has more to do with this than the metallurgy of the processes. Captain Shane feels that higher carbon would help. Whether this is so or not, I have no opinion, but I do feel that if quality of steel stands in the way we should not hesitate to accept a little more tensile strength and less ductility if it will ensure substantially improved soundness. But here again, I have not found foundrymen to agree that this concession would be helpful.

To revert in conclusion to the question of design: While we will continue our efforts in this direction, insistence upon much greater simplicity in design will, I feel, be futile. After all, in marine work at least, it is only for the complicated parts of the structure that we rely upon castings. For the simpler construction we can and prefer to use structural steel or forgings. If the designs now used for castings must be simplified we might as well go a little further and build them up of forgings, shapes and plates, welded together. In fact this movement is now well under way.

A FEW ADDITIONAL COMMENTS ON THE STEEL CASTING PROBLEM FROM THE NAVY'S POINT OF VIEW.

By K. D. Williams, Member.*

In our consideration of the steel casting question let us not forget the thousands of good castings in service and not condemn the many because of the failures of a few. We continuously hear the question "why not replace this casting with a forging." I will venture to say that more forgings than castings have failed in service aboard our ships.

Realizing that a good casting is often preferable to a forging, the Navy Department, particularly during the past three years has put forth every effort to remove the possibility of casualties due to defective castings.

Navy Department Specifications for steel castings have been criticized by the producers because of their restrictive clauses and by the users for their lack of definite process requirements.

It has often been proposed that a list of approved foundries be established and that purchases be made only from foundries which have demonstrated their ability to produce satisfactory castings.

The Navy's method of purchase by competitive bidding, which is based on law, and the necessity of accepting the lowest bid, precludes the establishment of such an approved list unless it can be established by the preparation of a set of requirements covering equipment and processes which each foundry must meet before being placed on such an approved list. A careful perusal of Captain Shane's article appearing in the February Journal certainly illustrates the futility of attempting to define what processes are necessary to produce satisfactory castings. He states that good castings are produced by basic or acid openhearth or electric furnace, the induction furnace and by the crucible method. Although Captain Shane is not in favor of the Tropinas method, we all

* Material Engineer, Metallurgical, Bureau of Engineering, Navy Dept.

know that perfect castings can be made by that method. What methods should be approved or what methods could be condemned without injustice? Some foundries employ internal chills, others external chills and still others use no chills, some use small risers others large risers, some use one kind of moulding sand others another kind of sand and still others use Chamotte. Some foundries obtain their fluidity by increasing the carbon content of their steel and depend upon subsequent heat-treatment of the castings to insure ductility; others use lower carbon, higher pouring temperatures and obtain sufficient ductility by a simple normalizing treatment. In fact there is no single method or procedure which insures perfect castings.

The Navy is interested in one thing only and that is obtaining good sound castings. The method which the manufacturer may elect to follow in the production of such castings is entirely and should be entirely the one he selects. The writer of a specification which contains detailed process requirements assumes responsibility for the results obtained. Since the present inspection force is inadequate to determine that detailed process requirements are carried out such requirements should be omitted from all specifications.

All steel castings in ships built at commercial yards whether they form parts of machinery, or are built into the hulls, are manufactured by the shipbuilder or purchased by the shipbuilder from a commercial foundry. The shipbuilder has always been permitted to exercise his judgment in selecting his source of supply. Although he has selected his source of supply, he has experienced as much difficulty in obtaining satisfactory castings as the Navy has in making its purchases on a price basis. The majority of castings now in service have been supplied by the shipbuilders.

During the past few years a broad minded policy has been followed by the better steel foundries in this country through their close association in societies and research committees. This policy has resulted in free discussions of difficulties encountered, means of avoiding such difficulties, and in liberal disseminaton of new ideas.

The Naval Research Laboratory Program was initiated primarily to benefit the Navy in the production of better steel castings

in its Navy Yards and develop methods of inspection to enable the detection of defects in castings submitted for inspection. Much has been accomplished by the development of the Gamma Ray.

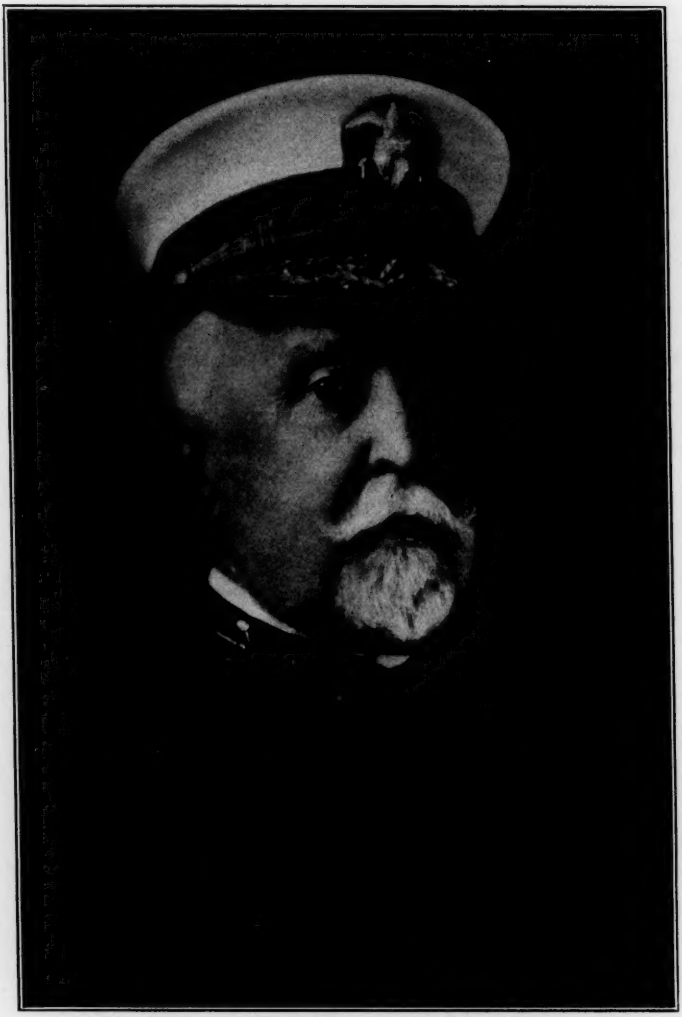
If by the determination of the strength of steels, during cooling from the liquid state, definite rules for the crushing strength of caves and moulds can be established and these rules are made available for use by commercial foundries the Navy doubtless will obtain many more castings free from hot tears.

When sound castings are assured the Navy will profit greatly in saving weight by employing the higher strength alloy steels in many of its castings.

The articles appearing in the February JOURNAL have attracted the attention of many designers and it is believed a much closer cooperation between the foundry and drawing room will result.

The business of the Navy Department is conducted by American citizens who are as proud of American products and accomplishments as any other group.

Constructive criticism of Navy specifications is always welcome. Advancements in Naval Engineering, both in design and in materials, are accomplished through trial installations and the helpful suggestions from representatives of commercial concerns.



REAR ADMIRAL R. S. GRIFFIN, U. S. NAVY

PRESIDENT OF THE AMERICAN SOCIETY OF NAVAL ENGINEERS

1908, 1912-13

REAR ADMIRAL ROBERT S. GRIFFIN, U. S. NAVY. AN APPRECIATION.

By Walter M. McFarland, Member.*

It sometimes happens that a public official has held an important office for a long time and performed his duties with great efficiency, including a crisis when the demands were very great and were fulfilled thoroughly, and yet his extreme modesty has kept his reputation almost confined to his professional associates, and the Nation which he served so capably hardly knows its obligation. Such was the case with Admiral Robert S. Griffin, U. S. Navy, who died February 21, 1933, after twelve years on the retired list, following two terms (or eight years) as Engineer-in-Chief of the Navy and Chief of Bureau of Engineering. His whole career in the Navy was highly creditable, but the period of great responsibility as Engineer-in-Chief is naturally the most important.

He was born at Fredericksburg, Va., September 27, 1857, and received his preliminary education there. He entered the Naval Academy in 1874 as a member of the first class of four-year Cadet-Engineers, which included others whose reputation was made after leaving the Service—Dr. Ira N. Hollis of Harvard and Worcester, Dr. M. E. Cooley of Ann Arbor and Dr. H. W. Spangler of the University of Pennsylvania. Griffin was one of the five honor men of the class. His first cruise was in Europe on the *Alliance* and the *Quinnebaug,* where he was associated with Chief Engineer John S. Albert, who had been director of Machinery Hall at the Centennial Exposition of 1876. This was followed by a cruise on the U. S. S. *Tennessee* until 1885. He was next on duty for about a year with the Naval Advisory Board where he had the benefit of training under Chief Engineer Alexander Henderson, whose executive ability and leadership were so helpful in forming the character of the younger men who served under

* Formerly Chief Engineer, U. S. Navy.

him. He spent more than two years in the Office of Naval Intelligence, and then went to the Bureau of Steam Engineering, where he was one of the assistants to that great leader in engineering, George W. Melville, who became Chief of Bureau in 1887. Griffin was one of his most valued helpers, being in charge of the correspondence with contractors. Melville appreciated very highly his technical ability and his remarkable memory; and, after his detachment for sea duty in 1890 used often to lament his loss, and his facility in the expression of keen, clear and vigorous English. From this time, all his shore duty was in the Bureau of Steam Engineering, where he showed great ability as an executive and engineer and where his wonderful memory, already referred to, made him useful and helpful to everybody.

Like Lord Macaulay, whose marvelous memory is praised by John Morley as having every fact right at hand, so it was with Griffin and he really became "a walking encyclopedia." In later years, people who did not know this often found themselves discomfited when their alleged precedents were found to be inaccurate or non-existent. He made a cruise on the *Philadelphia* until November, 1892, which was followed by duty as Inspector of Machinery for the *Bancroft* and a few months on that vessel. From 1893 to 1897 he was again on duty with Melville, to the great comfort of the latter. Then came duty on the *Vicksburg* and the *Mayflower*.

During the War with Spain he was Chief Engineer of the *Mayflower*, which was on blockade duty on the north coast of Cuba. As a result of location, he, like so many other officers, was not in the Battle of Santiago. His reward for faithful and efficient service was the loss of a number in consequence of the promotion of a classmate who was at Santiago but who had been below him. What can be said of the thrift of a government which rewards exceptional merit at the expense of other officers who have been just as faithful and meritorious but were not "on the spot at the time"!

In 1899, with the amalgamation of the Line and the Engineers, he became a Lieutenant, and like most of the former Engineers elected for engineering duty only. After a tour in the Bureau, he served from 1901 to 1905 on the *Illinois*, *Chicago* and *Iowa*, con-

cluding by duty as Fleet Engineer of the North Atlantic Fleet. From 1905 until his retirement in 1921, he was constantly on duty in the Bureau of Steam Engineering. In 1908 he became Assistant to the Bureau of Steam Engineering, of which Admiral Cone was Chief. In 1913 he succeeded him and continued as Engineer-in-Chief and Chief of Bureau until 1921. He was promoted through the various grades, becoming Commander in 1906; Captain, 1910; and Rear-Admiral (lineally), 1916. He was retired, on reaching 64 years, in September, 1921. In the Spring of 1919, he was one of the party of Bureau Chiefs who accompanied Secretary Daniels to Europe for an inspection of naval material and personnel.

Owing to remarks in high places, at the outbreak of the World War, about "keeping neutral even in thought" and the one, "Thank God! We were unprepared," it is probable that the general public has an idea that the Navy did nothing between 1914 and our entry into the War in 1917. The facts are quite the opposite. While it is true that the enormous increase in building dates from our entry, the preparation began almost immediately in 1914 in securing the latest information of all kinds and in laying out a definite plan for preparedness. As early as August, 1914, the Bureau arranged, with the Department's sanction, for a visit to Europe of Lieut. (now Captain) S. C. Hooper, one of the Navy's foremost radio experts, to be sure of our having the very latest improvements. Inspectors all over the country were called upon for reports as to the capacity of all works that could meet the needs of the Navy, and tentative plans were made for extensions and new works where necessary. The Act of August 29, 1916 provided for the largest building program ever authorized by any Congress. It included 10 battleships, 6 battle cruisers, 10 scout cruisers, 50 destroyers, 9 fleet submarines, 58 coast submarines and 13 auxiliaries. Of course, it would have been better if these had been authorized two years before.

The scope of the Bureau's work during the War was very wide and the amount enormous. The following skeleton summary gives some idea: "an enormous increase in the number of vessels and in the variety of the machinery equipment of the Fleet; the equipment and maintenance abroad of repair ships and repair

bases; the construction of destroyers, submarines, subchasers, Eagles, mine layers and tugs; the development of the devices for the detection of submarines; the creation of an organization for handling the power of aircraft; the production of helium in commercial quantities, and the establishment of numerous stations for the production of hydrogen for use in lighter-than-air craft; the enlargement of the machinery equipment of navy yards; and the maintenance of the large fleet of Naval Overseas Transport Service; the great extension of radio in shore stations and the Fleet."

One of the most important operations was the repair and rehabilitation of the machinery of the interned German vessels. Their crews had systematically wrecked the machinery so that they thought it would have to be rebuilt. Fortunately, the Engineer Officer of the New York Navy Yard, Commander E. P. Jessop, had been following the development of the welding of cast iron and bronze and was in touch with experts in such work. His recommendation led to investigation by the Bureau and the decision to make the repairs by welding. There was much opposition by those who believed it would be necessary to make new castings, but the immense saving in time by welding carried the day. The work proved entirely successful. "The military value of this work in the transport of troops is most interesting. The last of these ships was in service for nearly a year before hostilities ceased, and this is approximately the time saved by welding. They alone transported nearly 600,000 troops to France, the *Leviathan* carrying more than 94,000. The throwing into France of half a million United States troops a year ahead of the time estimated by the Germans for their arrival had a most important effect on the shortening of the war. It was these ships which enabled this huge force to reach France early and be trained at the front, so that they could do their share in turning the tide of war."

The repair ships and repair bases abroad were most important in the sustained efficiency of naval vessels and transports, especially the overworked destroyers. "The one thing that contributed most to the 'ever ready' condition of our destroyers in the war zone was the presence at Queenstown of the tenders *Melville* and *Dixie*. No job was too big for them to undertake, and it was

due to them that our destroyers based on Queenstown spent so little time at a dockyard. Other repair ships, the *Prometheus,* the *Panther* and the *Bridgeport* were stationed at Brest, and the *Buffalo* at Gibraltar, and performed like service for the patrol vessels and destroyers operating from those ports."

"During the War, all radio material work afloat and on shore was directed by the Bureau; this meant the maintenance of about 4000 ships and 210 shore stations. There was constructed from the Bureau's designs the high power station near Bordeaux, the most powerful station in the world, which upon completion was transferred to the French government. There was also constructed a station at Vladivostok for communicationg with our troops in Siberia."

In the account of the Bureau's work during the World War there has been given, in the language of chemistry, a qualitative analysis of the great diversity of its activity. It remains to present a brief statement, of the growth in amount of the Bureau's work during the Admiral's eight years as Chief, and fortunately we have his own account, which has been condensed.

The horsepower of the Fleet increased from 2,000,000 to 10,600,000 for ships actually completed, and from 384,000 to 2,475,000 for ships under construction, or about five and a half times as much power in 1921 as in 1913.

"During this time there have been added to the Navy 12 battleships, 295 destroyers, 95 submarines, 2 gunboats, 60 'Eagles,' 49 auxiliary vessels, and a large number of mine sweepers, tugs, yachts and submarine chasers."

The submarines represent an increase in horsepower of 73,000 and the Eagles 150,000. Vessels of the special type such as tenders, hospital ships, transports and supply ships, which in 1913 numbered 17 with aggregate horsepower of 63,000, now number 49 with 189,300 horsepower. There were 18 fuel ships in 1913, of 43,400 horsepower; in 1921 the number is 29 and the horsepower 136,300.

The transfer to Engineering of all the duties of Equipment which related to the electrical equipment of ships and to radio greatly enlarged the duties of the Chief of Bureau, and they have increased from year to year as the Navy has grown in size. To

the Bureau of Engineering were also assigned all the engineering activities connected with aviation from the introduction of this method of warfare until they were, on September 1, 1921, transferred to the newly created Bureau of Aeronautics.

One of the most important advances during the period was the adoption of electric drive (or reduction gear) for capital ships. The first use of electricity in this way was on the *Jupiter* (now the *Langley*), initiated by Admiral Cone. "The success of the installation on the *Jupiter* led us to believe that its adaptation to battleships would increase their military value. Careful studies confirmed this opinion and it was decided to make the first design for the *New Mexico* (1914). Since then all capital ships have been designed for this type of machinery."

"Great opposition was voiced by certain interests to the adoption of the electric drive for six battle cruisers, but the objections urged were not of sufficient weight or supported by sufficient facts to cause any change in the decision." As is now well known only two of these great vessels, the *Saratoga* and the *Lexington*, were completed, and then as airplane carriers. They have justified the Admiral's decision, and passed highly successful trials, wherein their designed horsepower of 180,000 was greatly exceeded. Fortunately, both Admiral Griffin and Admiral Dyson (Chief of Design) were spared to enjoy this triumph of their work.

"Enormous strides have been made in radio. The first high power station at Arlington was put in operation February 13, 1913, since which time other and more powerful stations have been erected at Darien, at San Diego, California, Annapolis, Md., and at Cayey, Porto Rico, all equipped with arc apparatus, whose successful development was fostered by the Bureau in the face of great opposition. The efficiency of long distance transmission and receiving has been greatly increased by the introduction of high speed instruments, and distant control of stations has been introduced. Compass stations have been established and the use of radio developed for aircraft and for strategical and tactical use."

The electrical equipment of ships has been marked by improvements in lighting systems, in fire control systems, in high-power search lights, and in interior communication systems. Submarines

have more than trebled in size, the power of the engines has increased five-fold, and of storage batteries and motors three-fold. The horsepower of individual destroyers has almost doubled, and mechanical reduction gear has been substituted for straight turbine drive.

"Besides the development from practically nothing in aviation to the present engineering standard, the transatlantic flight in 1919 was made possible by the novel arrangement of engines introduced by this Bureau, and by the application of radio for sending and receiving and also for navigational purposes."

"Another important event has been the transformation of the Fleet from coal burning to oil burning. This change had been made for destroyers prior to 1913 and two battleships had also been designed to burn oil, but these two vessels did not join the Fleet till 1916. All capital ships projected since these two are oil burning, as are also the battle cruisers, scout cruisers, mine sweepers, Eagles, and Fleet auxiliaries."

In another publication, also written in 1921, the Admiral discusses at great length the importance of the electric drive; and then, in another place has this to say, "That a design of machinery which is desirable in one type of ship may not be suited to the conditions that must be met in a different type is exemplified by the fact that the design for the scout cruisers is mechanical reduction gear and not electrical reduction. Although the horsepower of these ships is 90,000, the conditions of design and the limitations of space necessary to permit of all the military features to be embodied in the design made it impossible to install anything but a mechanically geared turbine." In other words, each design was made to suit the special circumstances—and this is first-class engineering.

Reference has been made to the Admiral's great executive ability. It is held by many that one of the greatest proofs of this quality is shown in the selection of assistants. Judged in this way, Griffin was remarkable. Among those who were his assistants, as Assistant Chief of Bureau, were Admiral S. S. Robison, afterwards Commander in Chief of the U. S. Fleet, Governor of San Domingo; Admiral R. H. Leigh, now the Commander in Chief of the U. S. Fleet, after having been Chief of Bureau of

Navigation; Rear-Admiral A. J. Hepburn, who has filled a number of most important assignments and is probably destined for still higher ones. When we entered the Great War and shore stations were filled by officers from the Retired List, he selected Captain O. W. Koester as Assistant Chief of Bureau, who made a remarkable record for efficiency, cooperation and promotion of confidence in the ability and fairness of government officials. Admiral Griffin told the writer, after the War, that he had been congratulated by another Bureau Chief on his "good luck" in getting Koester. His reply was, "I had him picked out for the job three years before we entered the War." Of other noted officers who served with him or under him and were influenced by the association may be mentioned Rear-Admirals J. K. Robison, John Halligan and S. M. Robinson, all of whom have been Chiefs of the Bureau of Engineering. A long list of younger officers who served under him could be made, all of whom have shown fine ability, are making a reputation in the profession, and will, in time, fill the more important positions.

His work necessarily brought him in contact with great numbers of contractors, and it is interesting to know that they all admired and respected his ability and thorough grasp of affairs, and also knew that he was absolutely fair and could not be swayed by partiality or prejudice. He was one of the most satisfactory men to whom a subject could be presented. He was a perfect listener, never interrupting the presentation of a subject unless the speaker had made an obvious mistake. If he wanted additional information, he waited until the end to ask questions. He had early accustomed himself to the mental solution of many arithmetical problems in an approximate way, which often surprised the modern devotees of the slide rule, who found that, while they were talking, he had taken their data and had the answer ready to check their figures. His long experience at the Bureau had given him a wonderful grasp of costs, and he had a card index, right at hand in his desk, so that he could almost at once check such matters. He had a very keen eye for important details, and many amusing stories could be told of how his quick glance would often detect an omission or mistake in an estimate.

It is most appropriate that this sketch of Griffin should appear in the JOURNAL of the SOCIETY OF NAVAL ENGINEERS for he was its first editor and gave it the form which has changed very little in the more than four decades of its existence. The writer had the pleasure of assisting him, and well remembers the care he took in keeping the cost within the resources. The membership at the start was small and we had no advertising, so that the annual dues constituted our capital. The first issue was less than one hundred pages, but it met with a very favorable reception and the size was increased with the greater revenue. The work of editor (and also Secretary-Treasurer) was absolutely a labor of love, but we were all young and enthusiastic in those days and there were some willing helpers. Griffin continued as Secretary and Editor for more than a year and was then succeeded by the writer. He was always keenly interested in the success of the Society and the JOURNAL; and was President in 1908 and again in 1912 and 1913; and was an Honorary Member. He was also a member of the Society of Naval Architects and Marine Engineers.

Admiral Griffin was elected as Honorary Member of the American Society of Mechanical Engineers in 1920. He also received the honorary degree of Doctor of Science from Columbia University and that of Doctor of Engineering from Stevens Institute of Technology. For his eminent services in the World War he was made a Commandeur de la Légion d'Honneur of France, and was awarded the Distinguished Service Medal by the United States.

After his retirement from the Navy, Admiral Griffin formed a partnership with the late Commander W. L. Cathcart as Consulting Engineers, with an office in New York City under the direction of Cathcart. As can readily be appreciated, for such work as expert witness Admiral Griffin was unexcelled, and he was frequently called or consulted in admiralty cases. After a few years the firm was dissolved by the death of Commander Cathcart.

Admiral Griffin also took a great interest in the Navy Relief Association and was very active, during his last years, in its beneficent work.

As is often the case with men of great ability, his personality was not striking at first glance. He was small physically, and probably never weighed 150 pounds at any time. He had a very

soft, quiet voice and could easily be shouted down by those who make up for lack of ideas by loudness of assertion. But, when it came to mental capacity and ability for planning and cogent exposition he was a great man. Intimacy with him inspired profound respect for his ability, simplicity and directness. He was not what is called a "great mixer" for he was essentially shy and very modest, but he was kind, generous and helpful, and as people got to know him well they became fond of him, and those whom he honored with his friendship loved him. He was very popular with his subordinates who were very numerous during the Great War. He was sincerely religious but quietly and unostentatiously. He was a devout member of the Roman Catholic Church, but his sympathies were wide, and his friendships were independent of religious affiliations.

When we contemplate such a record as this, our first thought is that it surely entitles the maker to enduring fame, but when we look back over history we are struck by the fact that high merit alone does not assure lasting renown. It seems that there must always be something of the spectacular, whether good or bad, or actions which have changed the whole course of history. We may, however, do our part in giving the record suitable publicity so that students of past events, especially those holding the same office or of the same profession, may find encouragement and incentive to the faithful performance of duty as it comes to hand, realizing that reputation and fame come not from deliberate pursuit but from duty well done as a result of adequate preparation and competence. In nearly all of our Wars there have been so many sad cases of incompetence and misfits. In the World War, the Navy was more fortunate, and Admiral Griffin is a shining example of ability, foresight and preparation which brought about complete success. The opportunity for rendering great service to the Republic found just the right man in position to render it efficiently and with distinction. The general public may not know its debt to this modest official, but we of the engineering profession are proud of the achievements of our distinguished leader, whose name will ever be associated with those other great engineering executives, Haswell, Isherwood and Melville, who were his predecessors as Engineer-in-Chief in troublous times and like him made history.

The writer felt that, notwithstanding his effort to pay a suitable and affectionate tribute to his dear friend of almost sixty years, it would be sadly incomplete without appreciative words from the distinguished men who were the Admiral's associates in his later years. A request to those who could be reached in time brought a ready response in the form of notes, which the writer has arranged, practically unchanged. Such a collection of words of praise and appreciation is not often assembled. It will be noted that these eminent men are all engineers, of one branch or another of the profession and that they all had an active part in the World War:

FROM ADMIRAL W. L. CAPPS.*

My first association with Admiral Griffin began nearly fifty years ago, when, just after my graduation from the Naval Academy in June, 1884, I, in company with others of my class, reported on board the U. S. S. *Tennessee,* flagship of the North Atlantic Squadron, of which Griffin was then the junior engineer officer. From the beginning, my association with him was particularly pleasant; and I learned to have the greatest respect and admiration for his personal and professional qualities. He was detached, as I recall it, after about a year, much to the regret of all his associates. I know that his services were greatly appreciated by his senior officers and that he was regarded by all as a young officer of great promise.

As noted above, Griffin's cruise terminated before mine and I did not again become associated with him, except for brief intervals, until we were on duty together at the Navy Department from 1905 to 1910. My duties as Chief of the Bureau of Construction and Repair brought me into frequent and close association with him at that time, since he was one of the principal assistants to the Engineer-in-Chief from 1905 to 1908 and Assistant Chief of the Bureau of Engineering during the last part of my tour of duty as Chief Constructor. My personal experience at that time strongly confirmed my original estimate of his unusual ability and knowledge of his profession, and I could at all times rely absolutely upon the accuracy and value of any professional opinions expressed by him.

* Formerly Chief Constructor, U. S. N., Chairman, Naval Compensation Board.

In 1915, two years after Griffin's appointment as Engineer-in-Chief, I again was on duty at the Navy Department in Washington as Senior Member of various Boards; and, in the early months succeeding the entry of the United States into the World War, Griffin and I were intimately associated as members of a special Board convened by the Secretary of the Navy to have cognizance of the costs of vessels about to be built under cost-plus contracts, involving a total expenditure of approximately $1,000,000,000. While this was very important, it was also very arduous duty and necessitated the closest cooperation between the various members of the Board. In all of this work Admiral Griffin, who was an ex-officio member of the Board as Chief of the Bureau of Engineering, rendering invaluable services; and again I found myself fortunate in having a colleague whose professional judgment was so sound and upon whose opinions I could rely with such confidence. During this last mentioned period, that is, from 1915 until Griffin's retirement in 1921, our association was continuous; and Griffin's contribution to our mutual efforts was in every respect most valuable. His whole habit of mind was direct, incisive, and sincere, and in handling the very large and difficult questions with which our Board was entrusted he could always be relied upon to devote his best energies to the proper solution of the problems entrusted to us.

Undoubtedly, the Navy Department was unusually fortunate in having at the head of the great Bureau of Engineering a man of Griffin's ability, experience, and temperament prior to and throughout the period of the Great War and during the settlement of the many complicated questions which arose therefrom. Although, in his official capacity, he undoubtedly had to make many decisions which bore heavily upon some of those directly affected, they could always feel sure that these decisions were prompted by a high sense of justice and the best good of the Service as a whole. There are, undoubtedly, on file many expressions from the Secretary of the Navy indicating the esteem in which he held his most efficient Engineer-in-Chief; but I have also the most definite personal knowledge that that official placed the highest value on the services of Admiral Griffin and had implicit confidence in his professional ability and wisdom. That Secretary Daniels held

him in the highest personal esteem is well evidenced by the fact that Admiral Griffin was one of the small group of officers who accompanied the Secretary on his European tour of inspection at the close of the Great War.

In concluding this brief record of my association with Admiral Griffin, I regard it as a great privilege to pay my personal tribute to the memory of this high-minded and distinguished officer, who, throughout his notable career, served his country faithfully and well and exemplified in his own life the very best traditions of the Naval Service.

FROM ADMIRAL HUTCHINSON I. CONE.*

I wish I could do justice in responding to your request for some notes to assist in preparing the obituary for my dear friend, Bobby Griffin. His gentle nature and loyal character were, it seems to me, best exemplified by the service he rendered as my assistant for four years in the Bureau of Engineering. He was, as you know, many years my senior, and his advice and constant care kept me out of many difficulties into which I might otherwise have fallen to my chagrin and sorrow. His ability, kindness and sense of humor were all of such a superlative degree as to be an unusual combination in one man. His memory of all engineering matters connected with the United States Navy for the past sixty years was so clear and accurate that I have always hoped he would record them so that they might be printed. His administration as Chief of the Bureau of Engineering needs no words of praise from me. He put into operation so many ideas with wonderful results to the Navy. My memory of him in his later years is the same as that of the years gone by when we served together, that he was the most progressive man of age whom I have ever known. He was always ready to undertake new things and this trait alone resulted in many improvements in engineering in the Navy.

FROM CAPTAIN O. W. KOESTER.†

If I were to say all I wish about our dear friend, there would be little else in the JOURNAL. As an executive, he had few equals and no superiors. His ability to foresee, plan and organize with

* Formerly Engineer in Chief, U. S. N., Chairman, U. S. Shipping Board.
† Assistant Chief, Bureau of Engineering during the World War.

respect to the Bureau's needs was often almost uncanny. His thorough grasp of all details of the situation during the World War was simply amazing. His professional ability in all branches of engineering involved in his work was the cause of admiration by all of us who worked with him. Being thoroughly advised of the necessities of the Service by study and investigation during the years preceding our entry into the War, he at once recommended the equipment and establishment of additional plants for forgings, machinery, materials, etc. The plants were built to the great benefit of the Service. His foresight was so keen that, at no time during the entire War, was the Bureau seriously hampered for necessary materials or supplies of any kind. I understand that you mention his great work in connection with aviation and with radio. I may be pardoned if I refer specially to the repair of the interned German steamers (with which I had much to do personally). His decision to make the repairs by welding instead of building new machinery saved the Government many millions of dollars, reduced the time needed by at least a year and was of supreme importance by enabling the delivery in France, a year earlier of about 600,000 United States troops. This undoubtedly ended the War sooner. It may be that it actually saved the day for the Allies. Immediately after the Armistice was signed, he took steps to reduce expenses. All work under the Bureau that was not 60 per cent completed was to be scrapped at once, and the clerical force reduced. By January 1, 1919, this force had been cut about 30 per cent. He was a brilliant officer, a wonderful executive, an accomplished engineer and a thorough master of the diversified duties of his office. He was an American gentleman in the very highest sense with a kind, generous heart and a helping hand for all about him. It was a joy to work with and for him. In my opinion, had anything occurred to disable Admiral Griffin during the World War, it would have been a national calamity.

FROM ADMIRAL S. M. ROBINSON.*

Early in 1921, at the request of the Historical Section of the Intelligence Division of the Office of Naval Operations, Admiral Griffin prepared a detailed report of the activities of the Bureau

* Engineer-in-Chief, U. S. N.

of Engineering during the World War. This report may be found in Publication No. 5 by the Office of Naval Records and Library of the Navy Department. In 1930, he was the author of an article on Marine Engineering published in the April, 1930, issue of Mechanical Engineering. In this article, he discusses the progress in naval propulsion engineering from about 1885 to the date of the article.

Admiral Griffin always enjoyed the confidence of his superiors and the admiration and respect of those who were associated with him. The honors which were conferred upon him were well-deserved. He was conspicuous for his foresight, progressiveness and his readiness to accept responsibility.

FROM ADMIRAL S. S. ROBISON.*

Admiral Griffin was not only a great engineer but a wise counsellor in every branch of the Naval profession, indeed, I might say on any subject brought to his attention. By this I mean that his mind was keenly analytical and the analysis led to practical suggestions for working out the problem. My service with and under him was enjoyable in the highest degree and profitable as well.

Before coming to the Bureau, I had been led to favor the use of boilers with small tubes on account of less danger of serious accident in case of the rupture of a tube. I found that Griffin had not overlooked this but was also weighing the importance of this point in connection with economy or efficiency of evaporation. At this time, the small tube boiler was not equal to the other. However, we were constantly experimenting at Philadelphia. As I looked over the reports, there came a time when the small tube boiler's efficiency was equal to the other. I then took the matter up with the Admiral with some hesitation as the matter was one on which he was an expert. So far from receiving a cold greeting, he was ready to discuss the matter from all points, efficiency, weight, safety. He told me to put the argument in writing so that we could give it careful consideration. The question of saving of weight for the greatly increased powers would probably have settled the matter, as has been the case, but I tell the story to show his open mind and the entire absence of resenting suggestions from his assistants.

* Late Commander-in-Chief of U. S. Fleet.

My experience on the *Jupiter* was similar in many ways. The electric drive (or reduction gear) had been decided upon during Admiral Cone's term, but was completed early in Griffin's. He approved of my going in command on her experimental cruise, as the electrical expert of the Bureau, so as to have first-hand information of the performance; the post of Assistant to the Bureau was kept open for my return. Before that time, Lieutenant Commander (now Rear-Admiral) S. M. Robinson and myself had sent in a report, based on the performance of the *Jupiter,* containing suggestions for the further use of the electric drive, and this report had been favorably received; Commander Robinson was ordered to the Bureau. He and I had a long conference with the Admiral and stated our opinion that the full military value of electric propulsion could not be attained in the *New Mexico* because she was designed for direct turbine drive, and that, while a decision was pending as to which form of drive to use, work was stopped. We recommended a center line engine room, one prime mover forward of the other, boilers on each side, and double bulkheads (10 feet apart) between the forward and after engine rooms. He listened and said, "Show me. I will give you facilities for making plans to scale, and then we will consider it further." Commander Robinson was given the necessary draftsmen, and in about six months he produced the drawings, every main and auxiliary item in place; each boiler in its own compartment. (We asked for boilers of 8000 horsepower each, but we were a little ahead of time. I believe the big boilers of today are of 12,000 horsepower). The Admiral followed and investigated the design thoroughly, was pleased with it when finished, and gave the order for its installation. Reading athwartship, the spaces were as follows:—explosion space; boiler room; engine room; boiler room; explosion space; summing up, about 97 feet beam for the ship, or adequate clearance for the Panama Canal Locks. This general arrangement has been followed in all battle ships since designed.

In 1909-10, when the question was under consideration of the destination of the Electrical Division of the Bureau of Equipment (on its dissolution), and I was writing reports for Assistant Secretaries, Aids for Material, Bureau Chiefs and others, I found Admiral Griffin a delightful, kindly, considerate and wise adviser

on everything pertaining to the situation. Later on, when I was transferred, with the Division, to his Bureau, it was the same. He fostered radio in all its ramifications.

He trusted his subordinates; read the letters prepared for his signature, and nearly always signed them. When he did not, he would send for the writer, state his objections and discuss the matter, so that the letter could be amended. He inspired loyalty.

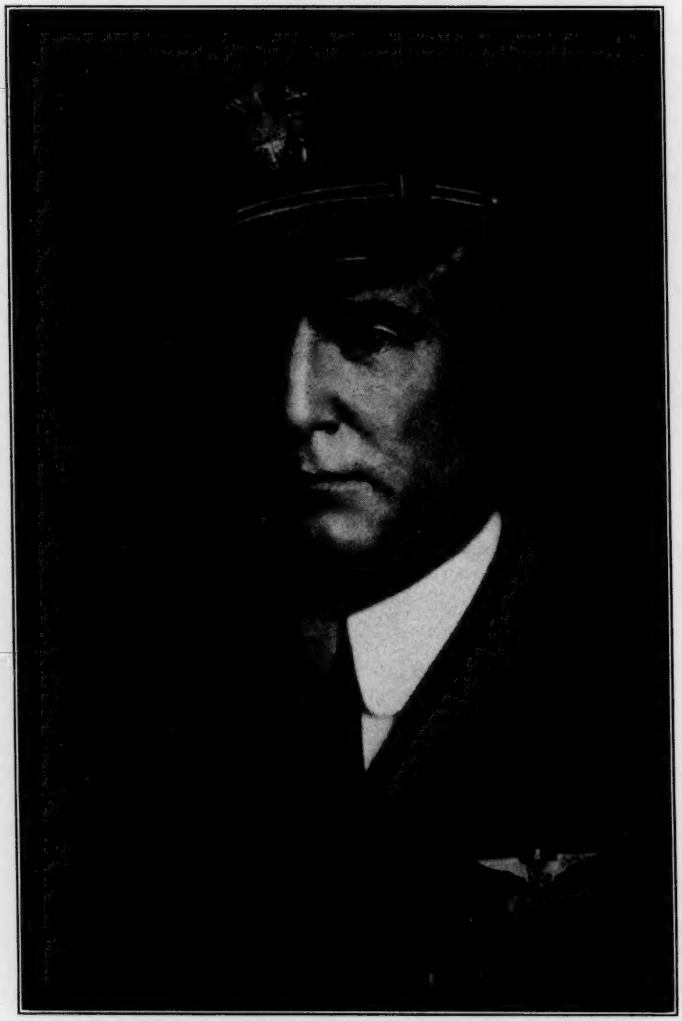
In 1914-15, we had many talks about the creation of the office of Naval Operations. Some Bureau Chiefs thought this would reduce the importance of their offices or hamper them in the conduct of business. He did not take that attitude and, after careful consideration, decided to support the movement, as an improvement in the shore organization, and advised as to the scope of the office of Chief of Operations. However, he was one of the first to check the tendency, of some subordinates in that office, not only to say what should be done but to tell the Bueaus how to do it.

Look at his War record, not only in all the things pertaining to dyamic engineering as usually understood (steam, electric, internal combustion) but especially in radio, which he did so much to advance. As a result we had the largest and best equipment in the world. At the Peace Conference, his young men, Bastedo, Le Clair, Hooper, and others, ran the communications. In central Europe, then in revolution, whenever a Peace Conference commission was sent, with it went his portable radio sets and men and officers to work them.

When we installed the radio stations at Panama, Honolulu and Cavite, the final responsibility was, of course, his. When the time came to test the station at Cavite, after all the money had been spent (and I may say that the site had been recommended by me, after a survey of conditions, while I was on the *Cincinnati* in 1912, made by the Bureau's order) and we were ready to press the button, he was the least nervous in the lot. We all thanked God when the button-key was pressed; it was heard not only in Honolulu but in San Francisco. If it had not worked—what then? Nobody knew, and we (he) would have had to bear the blame of failure. He never ran up on the roof of the State-War-Navy Building after a heavy storm to see if the Arlington Towers were still standing. He knew how to take the greatest responsibility

without the flicker of an eyelash. He was retiring and shy and averse to all pomp and ceremony. He would always make his visits to Navy Yards so as to avoid salutes. He was catholic in the broadest meaning of the word.

Summing up, he was a leader in his profession, a fine executive, competent and efficient in the conduct of his office; eminently fair and just in his dealings and with a keen sense of honor and integrity. He was kind and considerate to his assistants and subordinates; he had faith in them and trusted them, and he had their loyal and affectionate cooperation. It was a pleasure to work with him and under him and a wonderful training for younger officers in the bearing of responsibility.



Harris and Ewing, Photographers.

REAR ADMIRAL WILLIAM A. MOFFETT, U. S. NAVY

PRESIDENT OF THE AMERICAN SOCIETY OF NAVAL ENGINEERS

1933

REAR ADMIRAL MOFFETT, NAVAL OFFICER. AN APPRECIATION.

By Lieutenant T. H. Robbins, U. S. N.

All over the world the name of William A. Moffett means Naval Aviation. However, the creation and development of Naval Aviation as we know it was but the culmination of a brilliant career as a Naval Officer of the finest kind who won the ungrudging admiration of all Service people with whom he came in contact. He was a born leader, a keen technician, and a great student; and with these attributes he was a successful fighter dearly loved by his opponents as well as by his allies.

Probably his greatest quality was his patriotism. Born in Charleston, S. C., in 1869, shortly after the Civil War, he came to the Naval Academy with the intense love of country which is the heritage of the South. He was one of the rare men who do not take their daily work as a matter of routine, but rather as an end toward helping the country. He shaped his life keeping his eye on the broad question of how best to serve the Navy, with that as his one motive.

Prior to becoming the Director of Naval Aviation he held an enviable Service reputation as one of the most aggressive and astute Naval officers. During the Spanish-American War he served as an Ensign at the battle of Manila Bay with Admiral Dewey. Immediately after the battle he called on the Admiral of the Fleet to congratulate him on his victory. He was but an Ensign, fresh from the Junior War College course, who nevertheless felt so strongly the pride of patriotism that he must convey that feeling personally to his leader. Admiral Dewey was so struck by his character that he made him Captain of the Port of Manila, and shortly after gave him other important independent duty. During this assignment he was in charge of the salvaging operations of the enemy vessels that had been sunk in the harbor, and within a short time, with the assistance of many enemy workmen, cleared the channels and salvaged the ships. It was at this time that he had

his first taste of "high command," for, as the ships were brought up, he formed a small Navy of his own before turning them over, as a fleet, to the Admiral.

Following the Spanish War he served successively in the *Kentucky, Maine,* and *Maryland.* It was in the *Maine* that he first served in the Engineering Department of a ship, being assigned to Engineering duty in 1903. It was a hard and practical school, as he was the boiler division officer and the boilers were of the Niclausse type. Aboard the *Maryland* he was first Navigator and then Executive Officer, during which time the ship won the Battle Efficiency Trophy.

His next ship was the *Chester* which he commanded during 1913 and 1914. It was at this time that he participated in the occupation of Vera Cruz, being awarded the Congressional Medal of Honor for his services. The night before the occupation itself he took his ship into the inner harbor of Vera Cruz, without a pilot, when all navigating lights were out; he moored, and was in position to open fire the next morning at daybreak. It has been said that the fire of the *Chester* was of supreme value in the operations against the city. It is certain that she was nearest the enemy and did most of the firing and received most of the hits. His Medal of Honor was well merited, so well that even the officers of the British ships observing the action were enthusiastic over the way Commander Moffett had showed his skill. It is an interesting fact that the work of the *Chester* was so outstanding that that fine seaman, Admiral Cradock of the Royal Navy, took occasion to pay a special call on Commander Moffett to say that he had never seen a ship better handled or better fought.

In 1917 he was made Commandant of the 9th, 10th, and 11th Naval Districts, including command of the Naval Training Station at Great Lakes, Ill. Under his command it expanded during the World War from a small station to the largest recruit training depot in the United States. As the war progressed he enlarged the station until there were fifty thousand men under his command, and he furnished most of the trained personnel for all the various Naval activities during the period of hostilities. And it was here that he first became interested in Aviation, when he formed a training school for Aviation mechanics to serve abroad. Shortly there-

after he assembled several flight units for practical instruction. The Aviation units at Great Lakes developed so well that he saw the possibilities and benefits of a powerful air arm for the Navy, and later this did much to shape his future policies.

Leaving Great Lakes in the latter part of 1918, he took command of the *Mississippi*. As her Captain he again showed himself as a remarkable seaman and an inspired leader. The record of the ship during the two years he held her was outstanding both in Gunnery and Engineering; she took the athletic championship of the Fleet, and won the Iron Man. His crew had such respect for his seamanship that one morning it was found that the forecastle division had painted an "E" on the anchor, to match the many "E's" on the guns and stack.

In January, 1921, he reported to the Chief of Naval Operations and later became the Director of Naval Aviation. Shortly after that he assisted in the formation of the Bureau of Aeronautics, and was commissioned its first Chief with the rank of Rear Admiral, under an appointment from President Harding. He held this post for three terms, totalling about twelve years, being reappointed by Presidents Coolidge and Hoover. Within the first year of his office he took the regular Naval Observer's course at the Naval Air Station, Pensacola, since which time he was flown in almost every type of airplane and airship in the Navy. In fact he had more air experience than any other flag officer in any Navy in the world.

Upon taking office he saw that the paramount need for Naval Aviation was to serve the Fleet, and for the Navy to be able to operate planes and airships dependably. Therefore, he took as his first aim the development of Aviation in the Fleet, and to this end had seaplane catapults installed on all cruisers and battleships. Today the highly efficient part of a ship's gunnery department, which spots the fall of shot and "doubles" on scouting, the Aviation unit of one of our ships,—is the direct outgrowth of the first plan of Admiral Moffett on entering upon his new duties.

At the same time he stressed the development of large flying boats, capable of working with the Fleet, to the present point where these planes regularly fly over ten hours at sea in long range patrol operations. Today they are grouped in the Fleet Base Force where

they form an essential part of the scouting and protecting arm of the Navy. The technical and the operating efficiency of the great carriers is another monument to his foresight and knowledge.

In the engineering field, under his leadership the outstanding developments are the air-cooled engine and the airship. He recognized the Navy's need for an air-cooled engine for dependable operations at sea, and he encouraged and fostered its progress until that type of engine is the acknowledged leader in the aircraft world. The world's greatest airships were designed and built in America at his order, and the latest, the *Macon,* is about to take her place with the Fleet.

He conceived and carried out the Five Year Aircraft Building Program, which gave to the nation an orderly policy of aviation expansion for the Navy. During this time he saw the need for a healthy aircraft industry, and encouraged commercial aeronautics and the many struggling companies with his far-sighted advice. His work in that field shows itself in the many material developments which are still having a marked effect in airplane design, such as the transition from wood to metal construction, metal propellers, improved cowling, flotation gear, and solid injection type engines.

It was during the latter part of his career as Chief of the Bureau of Aeronautics that he served as Technical Advisor at the London Conference on Limitation of Naval Armaments. Here he evolved the "flying deck cruiser" and forced its recognition on the world as a new type of fighting vessel. In 1933 the projected Navy Building program pointed to the possibility of laying down one of these ships, in the construction of which he was so interested.

And in this highly technical phase in the life of the Navy he never lost sight of the fact that the most important service he could render was to produce a Naval Aviation whose personnel were inspired by a spirit of loyalty to the Navy above all. In spite of the many attacks upon it, thanks to Admiral Moffett, Naval Aviation has remained with as well as in the Navy. His spirit has produced an organization which will long remember and try to live up to his leadership, strength, and fighting blood.

REAR ADMIRAL H. P. NORTON, U. S. NAVY

PRESIDENT OF THE AMERICAN SOCIETY OF NAVAL ENGINEERS

1917-18, 1919

REAR ADMIRAL HAROLD P. NORTON, U. S. NAVY.

AN APPRECIATION.

By WALTER M. MCFARLAND, MEMBER.*

The death of Admiral Norton on February 11, 1933, after a long illness, removed an engineer who had filled important Naval positions, and was well known to the older members of the marine fraternity, especially those who were performing naval contracts. He was born in New York November 4, 1855, and educated in the Public Schools. He had started out in a mercantile career but had great natural aptitude for mechanics and drafting, in which he took instruction at evening schools. The special course in engineering at the Naval Academy had been established in 1871, and learning of this he entered the competitive examination and was admitted in 1874 as a member of the first class of four-year Cadet Engineers and graduated with the class of 1879.

He was easily the best draftsman in his class and distinguished in the practical side of marine engineering with a creditable standing in theory. In his last year he was the senior officer of the Engineer Division. The usual first cruise followed graduation, and then he was on duty in the Bureau of Steam Engineering and with the Naval Advisory Board, which supervised the building of the first steel ships of the "New Navy," familiarly known as the Roach cruisers. Then came inspection duty on the U. S. S. *Atlanta* and a short term with the Walker Board, under Secretary Whitney, where he was engaged in making sketch plans for some proposed new vessels. This was followed by a cruise on the *Atlanta,* where for a time he had the honor of being under Melville, famous Arctic explorer and afterward Engineer-in-Chief for sixteen years, during the upbuilding of the "New Navy."

His next duty was as assistant to the Chief of the Drafting Division of Steam Engineering (then the late Chief Engineer Nathan P. Towne). Here he had a fine opportunity for utilizing

*Formerly Chief Engineer, U. S. Navy.

his special talents. He had a marked capacity for order and system, and introduced numerous changes in the recording of data and other office details which were decided improvements and have served as the basis for present systems. A cruise on the *Concord* was followed by return to the Bureau, where he was in charge of the inspection and approval of contractors' drawings of machinery. At this time (1897) the Spanish War was looming in the distance. Experience with the new vessels in service had shown that the demands for fresh water had been underestimated and that the "single-effect" evaporators supplied were inadequate. The vital necessity for fresh "make-up-feed" for boilers was now well understood. It was proposed to have a fleet of tankers accompany the battle fleet. Norton had a much better idea. He proposed "distilling ships," where a "multiple-effect" battery of evaporators would supply about 20 pounds of water for a pound of coal burned under the boilers, so that a ship with a coal supply of (say) 3000 tons for distilling, would have a potential capacity of 60,000 tons of fresh water, equal to a fleet of ten tankers of the capacity of those days. Melville, ever quick to approve good suggestions (and to give the authors credit), backed this strongly and the idea was carried out in two vessels, the *Iris* and the *Rainbow*. The War was so short and the time needed for building and installing the apparatus (with all expedition) such that the vessels were not ready until the Fall of 1898, after the naval warfare was over. When the returned Army from Cuba was encamped at Montauk Point and there was trouble with brackish water, the Navy Department offered the use of one of these vessels for a supply of pure water.

Just before the declaration of War with Spain, we had purchased in England from the Armstrongs' two vessels, the *New Orleans* and the *Albany*. The former was near enough to completion for delivery, but the *Albany* was not, and work was suspended until peace was declared. Norton was sent over in 1899 as the Inspector of Machinery and subsequently made a cruise in her as Chief Engineer, from 1900 to 1904. While in England he made many friends, including such men as Sir John Durston, Sir Wm. White, Sir Chas. A. Parsons, Sir Alfred Yarrow, Sir Archibald Denny, Mr. A. E. Seaton, Mr. Sidney Barnaby and many

others of the leaders in marine affairs. His service on the *Albany* was on the China station and he also served there for a few months on the *Kentucky*. He was on duty at the New York Navy Yard from 1904 to 1906. In that year he was sent to Europe to study and report on turbine machinery, and in 1909 he made a similar trip for the same purpose.

He was Chief Designer at the Bureau of Steam Engineering from 1906 to 1910, covering parts of the terms of Admirals Rae, Parks and Cone as Chiefs of Bureau. During this time plans and specifications were prepared under his supervision for 12 battleships, 34 destroyers and numerous auxiliary craft. During this period, the first turbine driven battleships were designed and also the first turbine-driven, oil burning destroyers. At the close of his duty in this division, the first oil burning battleships were laid down, and the plans, specifications and estimates were well advanced. He was responsible for the application of forced lubrication for the main reciprocating engines in the Naval Service, the first installation being on the U. S. S. *Delaware*. During his term of office at the Bureau, considerable important investigation was made of the earlier designs of internal combustion engines for marine purposes, which had an important bearing on later investigations and the present development of the art.

After this he was on duty for about a year as General Inspector of Engineering Material, and then on special duty at the Bureau with additional duty as Inspector of Machinery for colliers building at Sparrow's Point, and also as Senior Member of Examining Board. In 1912 and 1913 he was on the Board for Inspection of Shore Stations and on various other boards. From 1913 to 1919 he was a member of the Naval Retiring Board, additional duty with Civil Service Commission, and various other boards.

It is interesting to note that the present method of determining the contract speeds of ships, by standardization on the measured mile, and then making an extended run at sea, basing the speed on the curve of speed and revolutions, was first proposed in a paper written for the American Society of Naval Engineers in 1889 by Admiral Norton and Walter M. McFarland (then both Assistant Engineers in the Navy). There was a clause providing a bonus and penalty for speed in the contracts for naval vessels of those

days which made the exact determination very important. The method then in use was by runs in opposite directions over a long course with vessels stationed at intervals to observe the tide and furnish data for the tidal correction to the apparent speed between terminii. This involved much labor and expense, and the actual speed was not known for a considerable time, often weeks. There was no way during the trial for the contractor to know what the ship was actually doing. The standardized speed curve gave full information every minute. The contractors were quick to see this important point and a few asked at once to be allowed to use it, but the Navy Department did not adopt the method until long afterward.

He had been duly promoted to Assistant Engineer and Passed-Assistant Engineer, and was one of the last to be promoted to Chief Engineer, early in 1899, just before the Bill of March 3, 1899, which amalgamated the engineers with the Line of the Navy. He then became a Lieutenant, and was promoted in due course through the various grades, becoming a Rear-Admiral July 1, 1918. He was retired for age November 4, 1919, and made his home in Washington. Until the exigencies of advancing years imposed restrictions on his activities, Admiral Norton took a keen interest in marine affairs. He was a member of the Engineers Club of New York; also a Council Member of the Society of Naval Architects, and a faithful attendant at the meetings; also a Past-President of the American Society of Naval Engineers. He was a member of the Metropolitan and Chevy Chase Clubs of Washington. He was a man of warm friendships and the circle of his friends was large. He was of agreeable personality, always conscientious and courteous in the performance of duty, fair and just to contractors while thoroughly loyal to the Government. He was accomplished professionally and proud of his connection with engineering. His record was distinguished for original and useful contributions, and for loyalty, integrity and efficiency.

NOTE. The writer is much indebted to Mr. H. B. Gregory of the Bureau of Engineering for valued assistance in the preparation of this article.

NOTES.

INDEX TO NOTES.

STEEL CASTINGS—CLEAN STEEL PRODUCED BY TROPENAS CONVERTER.
The Engineer, April 28, 1933.

THE RETURN OF THE CAPITAL SHIP.
The Engineer, February 3, 1933.

ARMORING OF WARSHIPS.
The Engineer, April 7, 1933.

BRITISH MARINE FUEL DEVELOPMENTS.
The Shipbuilder and Marine Engine Builder, March, 1933.

THE NAVY ESTIMATES FOR 1933.
The Shipbuilder and Marine Engine Builder, April, 1933.

ENGINE COOLING RESEARCH.
The Engineer, March 17, 1933.

STEEL CASTINGS.

Clean Steel Produced by Tropenas Converter.

The following article appearing in volume CLV-No. 4033 of April 28, 1933, of "The Engineer," published in London, is particularly of timely interest in view of Captain Louis Shane's article entitled "A Bird's Eye View of the Steel Casting Situation in Europe," which appeared in Vol. XLV, February, 1933, of the Journal of the A.S.N.E. Page 8 of that issue describes the soda ash process as developed by Messrs. Hertz, Christopher and Lightner, of the American Foundryman's Association. It is also of interest in view of the remarkable results obtained and the tendencies of various classification societies and government agencies to refuse to include castings produced by the Tropenas process in their specifications.

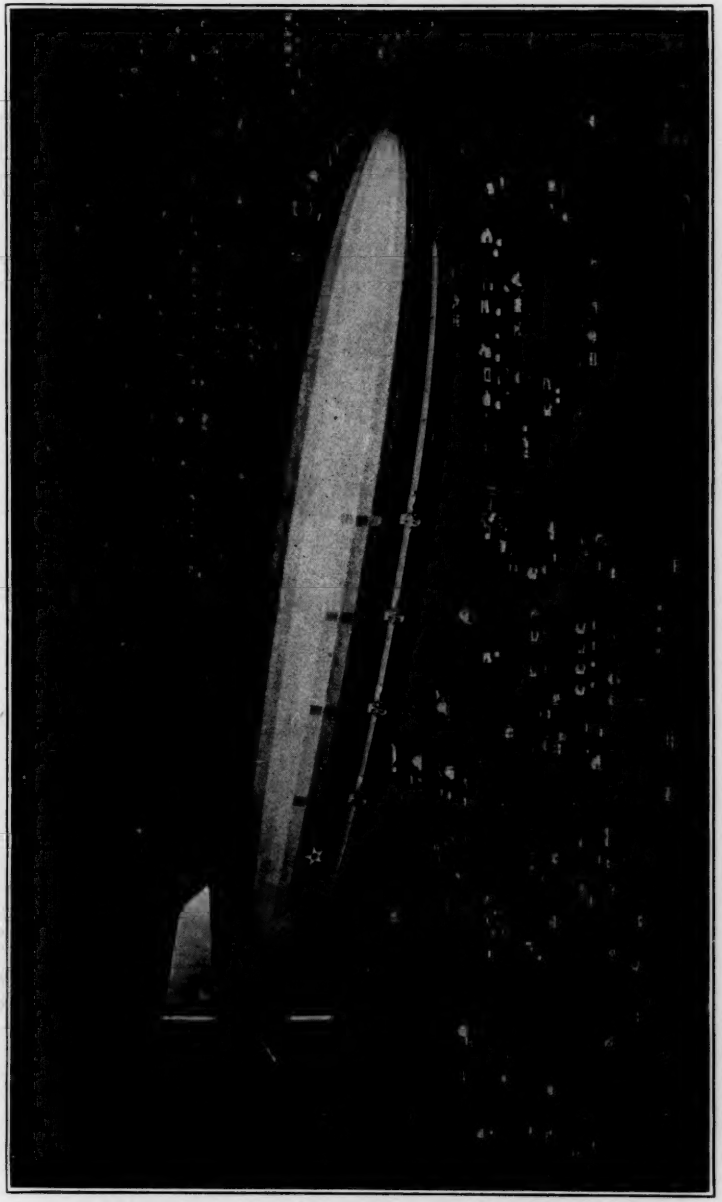
Some years ago we spent a most interesting day in exploring the steel foundry of Kryn and Lahy at the "Garden City," Letchworth, and then—see "The Engineer," June 19th, 1922—described the lay-out of the works and gave some account of the procedure followed there. Since then the general appearance of the factory has changed little, except that an extensive plant for the manufacture of oxygen for cutting purposes has been added; but the technique of steel casting has undergone considerable development, and on the occasion of a recent visit we were really astonished at the qualities of the steel castings now being turned out there.

Incidentally we might mention that the hope which we expressed some eleven years ago that the institution of the foundry would not spoil the amenities of the countryside has been justified. The surroundings, apart from the yard itself, now appear as rural as ever.

However, our concern at the moment is with a new class of steel casting which the company has recently evolved. It has an unusually high tensile strength, and yet retains all the ductility of steels of a much lower strength. The result is produced by making what might be described as exceptionally "clean" steel. That is to say, metal with a minimum of included foreign material. The presence of foreign material, slag, &c., in a casting naturally provides centers from which flaws may develop, while it also reduces the cross-sectional area of the metal available to withstand stress. By eliminating, almost entirely, foreign matter from the metal, Kryn and Lahy have succeeded in producing a cast steel with a tensile strength ranging from 35 to 40 tons per square inch that is, nevertheless, as ductile as could be wished. In support of this contention, we reproduce a photograph of a specimen which we recently tested at the works.

Although the British Standard Specifications require a bend test for steel castings of 26 tons minimum tensile strength, it has not, so far, been considered advisable to subject high-tensile castings of 35 tons and upwards to bending. The Letchworth steel will, however, withstand bending more drastic than is required of the lower tensile steel, while its elongation is also superior to that specified, but not necessarily tested by bending.

One specimen showed a yield point of 22.4 tons per square inch, a breaking strength of 38.4 tons per square inch, and an elongation of 25 per cent on 2 inches. The Brinell hardness number was 179. For the bend test its mate, which would not be required to meet the Standard Specification, was put in the machine and slowly bent to an angle of 135 degrees without the least sign of fracture. Being convinced that the metal would stand even more severe punishment, we suggested that the specimen should be put under the hammer. It was rather difficult to hold the specimen securely on



U. S. S. "MACON" ON HER FIRST TRIAL FLIGHT, APRIL 21, 1933.

the anvil of the hammer, but it was given four blows that closed it up into the condition shown in our engraving. The bruises caused by the blows of the hammer are plainly visible, and help to demonstrate the ductility of the material. Even after this severe treatment there was no sign of a crack on the outside of the bend, but strangely a small one slowly developed on the inside of the bend; it can be seen in the engraving, and was probably caused by a glancing blow as the specimen jumped off the anvil. However, such treatment of a casting is really unfair, and that it should have stood up to it so well is a good indication of the qualities of the metal.

Two other striking characteristics of these castings are that they are being made in competition with drop forgings in such simple forms as hand levers, and that the raw material is preponderatingly scrap steel.

At the present prices of scrap and pig iron, it is obviously desirable to use the utmost proportion of scrap, and the process adopted at Letchworth has enabled this policy to be carried to the extreme, so that cupola charges containing as much as 90 per cent of scrap are used, provided the scrap is of suitable composition.

It is certainly amazing to see such good steel being produced from such an assortment of scrap material. We were told that even detinned scrap such as is obtainable from old sardine tins would be usable if compressed to a sufficient extent to facilitate passage through the cupolas.

The cupolas are each capable of producing 6 tons of metal per hour, and they have been equipped by the British Drying and Heating Company, Ltd., of 14, Waterloo-place, London, S.W., with the Poumay system of additional blast. Under this system of operation, the melting of the charge in the vicinity of the main tuyeres is carried out with a minimum of oxygen, so that the rising gases contain a surplus of CO. The upper part of the cupola is, however, provided with another supply of air, tapped off from the main tuyere belt, and fed in at appropriate levels, which oxidizes the CO to CO_2, and consequently results in a corresponding economy of heat. The result is that the amount of coke used for melting the charge can be reduced by from 30 to 50 per cent, as compared with normal practice, and there is a corresponding reduction in the contamination of the steel by sulphur evolved from the coke. The auxiliary tuyeres for supplying the secondary air are arranged in a helix up the side of the cupola, and each one can be adjusted to give the desired amount of air.

After having been melted, the metal undergoes a further refining process. It is first teemed into a Tropenas converter, which acts for the time being as a mixing chamber. Then the contents of the converter are tipped into a ladle, in the bottom of which there has been placed a charge of soda ash. It is noteworthy that the ladle must be lined with a neutral refractory material, as it would otherwise be quickly corroded away.

The heat of the charge of metal, which is of the order of 1350 degrees C., decomposes the soda ash and produces a violent ebullition of CO_2. This ebullition thoroughly stirs up the metal and enables the sodium of the ash to interact with any sulphur in the charge, and produce a slag that is easily skimmed off the surface, so as to leave a ladle full of bright, clean metal. The charge is then returned to the converter and blowing started.

In the Tropenas converter the air is, of course, blown in at the sides just about the level of the surface of the metal, and the converter is gradually tilted as the blowing proceeds to subject all the metal to the oxidizing action of the blast. The tilting is effected by electrical gear and the attendant works to a timetable to ensure uniform results. The effect of the blast is to burn out the silicon, manganese, and carbon content of the charge, and to raise the temperature of the metal. The presence of silicon is initially desirable, as it helps in starting the oxidizing action. No aluminum is used.

The result of all the care taken in the melting process produces a steel which is remarkably pure and free from inclusions, a fact which is disclosed by micro-photographs, which we have examined. A typical chemical analysis of this steel is as follows: C, 0.3 per cent; S, 0.35; Mn, 0.8; S, 0.04; P, 0.05 per cent.

It is not necessary here to follow the steel from the converter through the process of casting, as it is orthodox practice. It is, however, noteworthy that great care is taken to keep the molding sand free from dust, so that the molds are thoroughly ventilated. Incidentally, the mixture of sand used in this foundry is so popular that it is supplied to several other foundries.

The castings are annealed after being taken from the molds, and for this purpose a number of furnaces have been provided, each equipped with recording thermo-electric pyrometers. The records from these pyrometers are all filed away, so that reference to the treatment of any cast can always be made.

There is a large fettling department where risers are cut off with oxy-acetylene burners, and the castings trimmed up with abrasive wheels. The wheels used are of the bakelite bonded type, and are run at a peripheral speed of 9000 feet per minute. The electric motors used for driving them have field rheostats that are periodically adjusted to keep up the cutting speed as the wheel wears.

In connection with the foundry there is a large machine shop where castings can be rough turned or finished to customers' requirements. A notable machine there is specially designed for rough turning locomotive wheel centers economically and expeditiously. It is placed in the erection bay, which is equipped with two overhead cranes, where also various types of oil engines, steam engines, condensers, compressors, and other plant are assembled.

We were gratified to learn that many of the orders which the company is now executing come from customers who have previously imported their castings from abroad.—"The Engineer," April 28, 1933.

THE RETURN OF THE CAPITAL SHIP.

Ten years ago the battleship's "expectation of life" was such as would have justified a very high premium against the risk of extinction. Distinguished naval officers at home and abroad condemned the great ship as an anachronism and prophesied its speedy disappearance. The five leading Powers had agreed to suspend this class of construction for ten years, and the belief was widespread that the capital ship had ceased to fill any useful *rôle* in modern naval tactics. To their credit be it said, the majority of British naval officers never subscribed to these radical views. Mature reflection on the lessons of the Great War had convinced them that the big ship, armed with heavy guns, was still the dominating factor, "the backbone of our naval power," as an Admiralty memorandum expressed it in 1921. Subsequent events appear to have vindicated their judgment; at any rate, several capital ships are now under construction, and there is every prospect of more being laid down in the near future. Germany took the initiative by starting, in the autumn of 1928, that much-discussed ship, the *Deutschland*. Although a pigmy compared with such monsters as the *Hood* or the two *Nelsons*, she carries an armament that places her definitely in the capital class, and it is not denied that she could engage in a long-range duel with almost any battleship or battle cruiser now afloat with a reasonable chance of survival. This, we believe, to be a fair estimate of a ship that has a

broadside of six 11-inch guns, protection equal to that of a pre-war armored cruiser, and a speed that would enable her to choose her own range in action with any battleship. It is certain that her fighting powers are immensely superior to those of the 10,000-ton cruiser type, mounting 8-inch guns, which the Washington Treaty foisted on the naval world, and fifty-five units of which have been built to date in Europe, the United States, and Japan. None of these hybrid craft could stand up to the German "pocket battleship," though she is no larger than they. As we write, the *Deutschland* is running her preliminary trials at sea, and all who appreciate boldness and ingenuity in the realm of technical development will share our hope that this remarkable warship will fulfill every anticipation of her designers. A sister vessel, *Ersatz Lothringen,* is to be launched on April 1st, and a third unit, *Ersatz Braunschweig,* was laid down in October last. It is proposed to begin a fourth next year.

As might have been predicted, the building of these small but powerful capital ships has produced repercussions in the naval world. They have depreciated the value of the 10,000-ton cruiser to such an extent that the construction of the type has virtually ceased, the United States being the only country in which it still finds favor. France has deemed it expedient to build a battle cruiser as a retort to the German vessels. This ship, the *Dunkerque,* which was begun at Brest in December, is the first full-scale capital ship to be laid down anywhere for ten years. From plans and details published in the French Press she is seen to bear a family resemblance to the *Nelson* class. She will displace 26,500 tons, the contract speed is 29 knots, and the armament is to comprise eight 13-inch and twelve 6.1-inch guns. Both main and secondary armaments are to be grouped in quadruple turrets. The 13-inch gun positions are on the centerline in the fore part of the ship, the second turret being well in rear of, and at a higher elevation than, the first, this arrangement permitting the discharge of all eight guns directly ahead. In each turret the four guns are mounted in pairs, separated by a stout bulkhead. Each pair of guns is worked independently. On the other hand, all four weapons must, of course, be trained on a common point of bearing and will, therefore, be equally affected by errors in deflection. It is also evident that the system of shell and powder hoists must be very complicated in view of the abnormal space between the wing guns and the necessity of keeping the magazines well away from the sides of the ship. The 6.1-inch guns are in quadruple turrets disposed pyramidwise in the after part of the ship, one turret on either beam and the third on the quarter-deck. There is also a number of anti-aircraft pieces and torpedo tubes, the details of which are uncertain. No definite particulars of the ship's protection are available, but it is reported unofficially that a waterline belt of not less than 9-inch thickness will be associated with two strong decks and elaborate subdivision. The concentration of the main and secondary artillery in multiple turrets tends to reduce weight and centralize protection, but never before has it been carried to such a length. In the *Dunkerque* a single well-placed shell might put half the heavy guns out of action, and remembering the phenomenal number of turret hits registered at Jutland, we should not care to see the armament of a British ship disposed on the same principle. The next Power to resume capital ship construction may be Italy, whence it is reported that tentative designs have been prepared and tank experiments conducted with a view to the building of such a vessel. Unless, therefore, a new naval "holiday" is agreed to by all the major Powers without delay—an improbable contingency, since it would involve the scrapping of the *Dunkerque* and several, if not all, of the *Deutschlands*—battleships are certain to reappear in the building programs of this country, the United States, and Japan, when existing treaties expire in 1936. This circumstance

lends interest to such forecasts of our future capital ships as have been made. In the official British plan of disarmament tabled at Geneva last year a restriction of capital ships to 25,000 tons and 12-inch guns was proposed, with an alternative limit of 22,000 tons and 11-inch guns provided that cruiser tonnage and armament were drastically reduced. Taking the higher figures as a basis, Sir George Thurston has outlined in the new edition of "Brassey's Naval and Shipping Annual" a project for a battleship adapted to British requirements. This is a vessel 560 feet in length, with a beam of 92 feet, and a draught of 29½ feet at 25,000 tons standard displacement. She would be equipped with geared turbines and small-tube boilers, the plant developing 30,000 H.P. for a speed of 22 knots. A 12-inch waterline belt, tapering at the extremities, 14-inch barbettes, and 7-inch armor on the citadel containing the secondary armament, are features of the protective system. There would be two armored decks in way of machinery, magazines, and barbettes, of a combined thickness of not less than 6 inches. "The underwater protection against submarines and mines to consist of a slight swelling out, or 'bulge,' incorporated in the vessel's structure, with at least two longitudinal bulkheads, one armored; one placed about midway between the shell and the inner bulkhead, which latter should be kept as far from the side as machinery and magazine arrangements will allow." The armament proposed is twelve 12-inch guns in triple turrets, grouped in pairs forward and aft; twelve 6-inch guns in a broadside battery; eight 4-inch or 4.7-inch A.A. guns, and two 21-inch or 24-inch torpedo tubes. A complement of seaplanes with launching gear, and possibly an outfit of mines and depth charges, is suggested.

With many of the features of this design we find ourselves in agreement. We should, however, prefer a shorter and broader ship, the substitution of eight 13.5-inch guns on twin mountings, for the twelve 12-inch in triple turrets, and the deletion of all torpedo tubes, mines and depth charges. It is true the 12-inch gun was recommended in the British program at Geneva, but with the tacit proviso that no greater caliber be adopted in any navy. On the other hand, neither the United States nor Japan has shown any disposition to accept this limit, and France has definitely repudiated it by arming her new battle cruiser with 13-inch guns. We are, therefore, of opinion that a restriction to 12-inch is impracticable. The 13.5-inch firing a 1400-pound projectile, is a weapon of proved value, accurate, hard-hitting, and easy to manipulate. Moreover, a ship armed with this gun need not shirk action with an opponent carrying 15-inch or even 16-inch metal. And, finally, we know that the vast majority of British gunnery officers look askance at triple mountings, and much prefer the well-tried system of twin turrets. Except by torpedo specialists the fitting of torpedo tubes in capital ships is regarded as a useless encroachment on space and weight, while the carriage of mines or depth charges by such vessels would seem equally futile. As for the relation of beam to length, it may be that a long and narrow ship is better able to keep her speed in a seaway, but for a 25,000-ton ship designed for 22 knots this principle is unimportant. Much more to the point is the fact that ample beam gives better protection against underwater attack. The thickness and distribution of armor suggested by Sir George Thurston appears to be satisfactory, and with the modifications we have indicated we are inclined to accept his forecast of the future capital ship of the British Navy as sound. It will not be forgotten that his prediction of our post-Washington battleships and cruisers proved accurate in all essential features. —"The Engineer," February 3, 1933.

THE ARMORING OF WARSHIPS.

The so-called "pocket" battleship *Deutschland,* which was formally commissioned on April 1st, is officially designated a *Panzerschiff, i.e.,* an armored ship, to distinguish her, no doubt, from the light cruisers which preceded her in the reconstruction of the German Navy. It is, however, obvious that the armor protection of this vessel is nothing like as heavy as that of the conventional capital ship. To have compressed an armament of six 11-inch and eight 6-inch guns into a ship of only 10,000 tons, with machinery of 56,800 H.P., is a striking achievement in itself, but the residue of weight available for protection must perforce be limited. In our view, the *Deutschland* was designed not as a ship of the line, but as a heavily gunned cruiser, in which case her protection would be adequate if it afforded her a reasonable measure of security against 8-inch gun attack, this being the largest caliber now mounted in cruising ships. Unofficial accounts credit her with a 5-inch belt on the waterline, rather narrow and extending between the forward and after barbette bases. Beyond these positions there are strakes of thinner plating, but a considerable length of the hull at bow and stern is bare of armor. There is 7-inch armor on the barbettes, and the horizontal protection comprises two decks, with a maximum thickness of 5 inches. Pending verification, these figures must be accepted with reserve, suggesting as they do a total weight of armor which is difficult to reconcile with the other features of the ship; but even if they be accurate they stamp the *Deutschland* as an armored cruiser rather than a capital ship. In any case, her protection is unquestionably superior to that of any post-war cruiser, and this fact, coupled with the formidable armament, endows her with a special degree of tactical value.

The German naval authorities, like our own, possess a wealth of technical data derived from the war. As regards the problem of armor protection, their experience may well be unrivalled, in view of the number of German ships that remained afloat, and were able to return to harbor after enduring very severe punishment by gunfire. In so far as the limited displacement permitted, the conclusions drawn from an exhaustive study of these data have certainly been incorporated in the *Deutschland.* It is therefore interesting to detect some similarity in the armor protection system of the German vessel to that of H.M.S. *Nelson,* an earlier product of war experience. In either case the horizontal defenses are particularly strong, the *Nelson* having a 6¼-inch deck over her vitals, yet both ships have the heaviest waterline belt consistent with other demands on weight. What inferences are suggested by this parallel? We have heard often enough that future actions at sea will be decided, so far as gunnery is concerned, by plunging fire. The guns will open at extreme range, and the angle of descent of the projectiles will be so steep that they will come crashing like meteorites through the decks of the target. Hence the necessity for the stoutest possible horizontal protection, to reinforce which, it is contended, the side armor must be ruthlessly sacrificed. After the war capital ship designs were published showing a thick vaulted deck enclosing all the vulnerable spaces, but no belt armor of any importance, and these plans were put forward as the nearest approach to the ideal method of defense. Fortunately, as we think, they were not adopted by the Admiralty, for they were based on a number of premises too hypothetical to appeal to the practical naval mind. If actions were always to be fought in perfect weather, with the sea like a mill pond and visibility at its maximum, something might be said for the prospects of decisive gunnery at ranges up to 30,000 yards. But weather conditions represent the principal unknown quantity which restrains the

naval expert from designing ships to conform to this particular theory of tactics. In the future, as in the past, ships or fleets may have to engage at ranges at which the trajectory is comparatively flat, and it is then that the vessel with massive decks but thinly armored sides would be exposed to mortal blows. Conversely, plunging hits are always a possibility to be reckoned with; hence the necessity of stout plating over machinery and magazine spaces. Nor must air bomb attack be ignored in this connection, though its menace may easily be exaggerated. On the whole, naval opinion at home and abroad appears to be becoming more or less unanimous on the general principles of armor protection. For example, there is a perceptible and universal recoil from the "egg-shell" type of cruiser, packed with machinery and overloaded with guns, but devoid of armor capable of resisting serious blows. These, it is now recognized, are not true fighting ships. So far as the demands of armament and speed permit, the latest 10,000-ton cruisers building abroad carry armor over the most vulnerable sections, though it is not pretended that their plating would stand up to 8-inch gun attack. Turning to smaller cruisers of recent design, the majority of these have some armor on the waterline, and in most cases the guns are mounted in twin or triple turrets which, though unable to resist direct hits, do afford the crews protection from splinters. The open gun shield which proved such a death trap in the Great War has been discarded. It is, of course, impossible to give adequate armor defense to ships of high speed and moderate tonnage, but when, by sacrificing a few knots, an extra inch or two of steel can be interposed between enemy gunfire and the vitals of the ship and her *personnel*, the loss of speed ought to be accepted. That principle appears to govern current cruiser design in this country, and it is noteworthy that France and Italy, which until recently placed speed before everything, are providing their latest ships with substantial protective plating. In view of the embargo on capital ship construction which in the case of this country, the United States, and Japan will remain in force until 1936, it may seem premature to discuss the probable features of our future battleships. It may, however, be taken for granted that tentative designs for such vessels are already in existence. There is good reason for believing them to be much smaller than the *Nelson* class of approximately 34,000 tons. The British disarmament program postulates a maximum of 25,000 tons for capital ships, and unless this limit is greatly exceeded by other Powers it will probably be adhered to in our future designs. A restriction of gun caliber to 12 inches has also been recommended by Great Britain, but finds little support elsewhere. Japan favors a maximum of 14 inches, while France has actually laid down a capital ship to mount 13-inch guns. In these circumstances an armament of 13.5 inches appears to be indicated for British ships, which may mount either nine guns in triple turrets or eight in twin turrets, the weight being practically the same. A contract speed of 21 knots would satisfy most naval officers. Here, then, we have a battleship equivalent in tonnage and speed to the *Iron Duke* class. As, however, the armament is lighter by two 13.5-inch guns—in terms of total weight—and improvements in boilers and turbines would enable machinery of 30,000 H.P. to be installed at considerably less weight than that of the *Iron Duke* plant, a much larger proportion of the displacement would be available for armor protection in the new ship than in the old. The latter had a 12-inch belt, 10 inches to 11 inches on the gun positions, and horizontal protection up to 2½ inches maximum. In the new ship it would be desirable to reinforce the turret armor and provide much stronger decks, but otherwise the general defensive system might with advantage be retained. The beam,

however, should be increased to allow space for better subdivision as a defense against torpedoes. In theory, it is true, 12-inch armor can be penetrated by the heaviest modern naval guns at ranges up to 17,000 yards, but calculations based upon muzzle velocities and proof-butt results are not always reliable.

If the Geneva negotiations result in establishing a maximum of 14 inches for capital ship guns, there would, in our opinion, be no necessity to go above 12-inch armor in future vessels. One proposition appears to be indisputable—adequate armor protection is indispensable to any warship above the smallest cruiser category, and high speed is in no sense a substitute for such protection. This truism, it may be recalled, was strongly emphasized by the present First Sea Lord of the Admiralty, Admiral Sir A. E. Chatfield, in a discussion at the Institution of Naval Architects some years ago, and there is evidence that his views are shared by all naval authorities in this country who have pondered the technical lessons of the war.—"The Engineer," April 7, 1933.

BRITISH MARINE FUEL DEVELOPMENTS.

Those in this country—and there are many—who regard the more widespread use of coal or its derivatives for marine purposes as an essential preliminary to the return of more prosperous times, must have been greatly heartened by the series of important developments which have taken place within the last few weeks. Arranged in order of significance, these developments include (1) the placing of the first order by the British Admiralty for a 12 months' supply of oil fuel produced from British coal, (2) the practical and very informative paper on "Pulverized-coal Firing in Marine Scotch Boilers" read before the Institute of Marine Engineers, and (3) the interesting description of the research work undertaken by Mr. Stephen L. Wyndham on colloidal fuel as recounted to the Society of Consulting Marine Engineers and Ship Surveyors.

Each of these developments is representative of an enormous amount of effort and research, and the common objective has been to render commercially practicable more advantageous methods of employing British coal as a marine fuel. The Admiralty contract, in particular, is of the utmost significance to the coal industry, as it also must be a great source of encouragement to Low-temperature Carbonization, Ltd., and to other companies or bodies who have been engaged on parallel researches into the production of oil from coal by alternative processes. This order represents the culmination of extended research and experiment by the company named towards standardizing a fuel distilled from British coal to comply with the existing Admiralty specification. The oil is a by-product derived from the manufacture of smokeless fuel. It is highly fluid, freely flowing, normally requires no pre-heating, and leaves no deposit. The first bulk consignment of this coal-oil was delivered to the Admiralty by the company in December last, and in the interval exhaustive trials have been undertaken with the new fuel in H.M.S. *Westminster*. It is understood that the calorific value of the coal-oil is very satisfactory and that its price is competitive with that usually charged for high-grade petroleum oil. In ordering a year's supply of this coal-oil, the Admiralty have not merely given welcome encouragement to the coal industry, but have shown that they are fully alive to the strategical importance of developing dependable alternative sources of oil-fuel supply. The almost complete dependence of the British Navy upon imported oil fuel

and the recent dispute *in time of peace* regarding the Persian oilfields, to which our Navy looks for a material proportion of its supplies, constitute together the strongest possible argument in favor of encouraging by every possible means the development of home-produced fuel for the Navy.

With regard to the second of the three developments noted, there has been a tendency in recent years to discount the potentialities of pulverized-coal firing for marine purposes, both in this country and abroad. It cannot be gainsaid, of course, that numerous complex and not wholly anticipated problems have had to be solved in the burning of pulverized coal on board ship, and the system as a whole has undoubtedly suffered from the unduly optimistic and excessive publicity which it received at its inception a few years ago. The paper already mentioned, which was prepared by Mr. W. G. Gibbons and Mr. M. Arthurson, described in commendably practical language the experience which the Harrison Line, of Liverpool, had encountered in the successful operation of two ships—the *Musician* and the *Recorder*—over periods of 3½ and 2½ years respectively using pulverized fuel prepared on board from slack coal. The *Recorder* is one of nine sister ships, the other eight being hand-fired coal-burners; and, accordingly, unusually favorable circumstances existed for arriving at reliable comparative performance data. This comparison shows that the pulverized-coal burning vessel has achieved an average economy of 25 per cent in fuel costs, with a simultaneous saving in the shape of reduced personnel. There has been no involuntary stop at sea with the *Recorder*, and the wear and tear and the maintenance of her boilers have been less than the average of her sister ships, while the efficiency of performance is gradually being improved each voyage, due to the increasing familiarity and experience of the staff on board. The meeting at which the paper was submitted was one of the most outstanding in the history of the Institute, prominent among those present being representatives of the Mines Department, the Admiralty and the principal steamship companies. The owners and the makers of the plant—Messrs. Clarke, Chapman & Co., Ltd.—alike are to be congratulated on having made public such valuable operating data, which cannot fail to benefit the cause of pulverized coal, and to interest a wide circle of marine engineers, as well as all who are directly connected with shipping.

As to the last of the developments mentioned, Mr. Wyndham touched upon the interesting practical experiment conducted by the Cunard Line last year, when the *Scythia* was operated for one voyage with one of her boilers burning colloidal fuel comprising a mixture of oil and coal in the proportion of 60 and 40 per cent, respectively, and proceeded to describe the experiments which he himself had been conducting. The processes of milling required to bring the coal dust to that superfine state essential for complete and intimate binding with the oil in the form of a stable mixture were dealt with in detail, as well as the difficulties which have had to be overcome in designing a satisfactory burner to prevent coking at the tips. These experiments are being continued; and although there are still a number of operating problems connected with colloidal fuel awaiting solution, the prospect which it offers of developing the wider use of British coal as a partial alternative to imported oil is of such national importance that such research is worthy of the highest commendation.

As the leading maritime nation and possessed of valuable coal resources, we, more than any other nation, are vitally concerned with the subject indicated by the title of this article. Large-scale users of oil fuel, such as the Admiralty and the leading passenger-liner companies, are never likely, under prevailing international and competitive conditions, to revert to coal as a fuel in its raw hand-fired state. The three lines of development which have been

discussed, however, offer each in its own way promising and desirable alternative methods of using British coal, and concentration upon such constructive systems is much more likely to be attended with success than any organized "back-to-coal" movement in its primitive medieval form.—"The Shipbuilder and Marine Engine-Builder," March, 1933.

THE NAVY ESTIMATES FOR 1933.

The Navy Estimates for the financial year 1933 (1st April, 1933, to 31st March, 1934) were issued on the 9th March. Like those for 1932, they have been restricted by the exigencies of the financial situation; and, according to the accompanying statement by the First Lord of the Admiralty (the Rt. Hon. Sir Bolton Eyres-Monsell), they do not fully provide for all the potential needs of the Navy. The net total for 1933 is £53,570,000, and exceeds the net total for 1932 by £3,093,700.

Of this increase no less than £2,355,360 is required in order to make normal progress with new construction. It will be recalled that a large part of the normal expenditure upon shipbuilding in 1932 was deliberately retarded and heaped into subsequent years by the temporary expedient of deferring the orders for the 1931 Program.

THE NEW SHIPS OF THE 1933 PROGRAM.

The new-construction program for 1933 is as follows:—

Four cruisers (probably one *Leander* and three *Arethusas*);
One destroyer-flotilla leader;
Eight destroyers;
Three submarines;
Three sloops;
One convoy sloop;
One coastal sloop;
Four yard-service lighters;
Two refuse lighters;
One boom-defense vessel;
One boom-working vessel.

The four cruisers (there were only three provided for in the 1932 Estimates) constitute the fourth and final instalment of the replacement program due for completion by the 31st December, 1936, under the terms of the London Naval Treaty.

The numbers of destroyers and submarines are the same as in previous building programs since the Treaty.

As in previous years, suitable allowance has been made for anticipated under-spending on contract work, etc.

Of the 29 ships to be laid down in the financial year 1933, one cruiser is to be built at Devonport Dockyard and one at Portsmouth Dockyard, one submarine at Chatham Dockyard, one sloop at Devonport Dockyard and one at Chatham Dockyard, one yard-service lighter at Malta Dockyard and two at Simonstown Dockyard, and two refuse lighters at Malta Dockyard; or 10 vessels in all.

Nineteen vessels in all are to be built by contract, *viz.*, two cruisers, one flotilla-leader, eight destroyers, two submarines, one sloop (minesweeper), one sloop (convoy), one sloop (coastal), one boom-defense vessel, one boom-working vessel, and one yard-service lighter, the last-named for service at Hong Kong Dockyard.

The sums provided for expenditure on the vessels to be laid down in the Royal Dockyards are trifling, *viz.*:—

Cruiser at Devonport	£685
Cruiser at Portsmouth	£690
Submarine at Chatham	£1310
Sloop at Devonport	£475
Sloop at Chatham	£545
Yard-service lighter at Malta	£2680
Two yard-service lighters at Simonstown	£2108
Two refuse lighters at Malta	£2315

The only provisions made for expenditure during the financial year on the vessels to be laid down in private yards are as follows:—

Two submarines	£2400
Sloop (convoy)	£6518
Sloop (coastal)	£6518
Boom-defense vessel	£5014
Yard-service lighter for use at Hong Kong	£1353

SHIPS COMPLETED AND UNDER CONSTRUCTION.

The four cruisers of the 1929 and 1930 Programs—the *Leander, Achilles, Orion* and *Neptune*—which have to be completed at various dates between March, 1933, and February, 1934, will be commissioned for service in the Second Cruiser Squadron.

Of the 1930 Program, the flotilla-leader *Duncan* (Portsmouth Dockyard, with machinery by Messrs. William Beardmore & Co., Ltd.), will shortly join the First Destroyer Flotilla in the Mediterranean Fleet. The eight destroyers, *viz.*, the *Defender* and *Diamond* (Messrs. Vickers-Armstrongs, Ltd.), *Dainty* and *Delight* (Fairfield Shipbuilding & Engineering Co., Ltd.), *Diana* and *Duchess* (Palmers Shipbuilding & Iron Co., Ltd.), and *Daring* and *Decoy* (Messrs. John I. Thornycroft and Co., Ltd.), are replacing older vessels in the Mediterranean.

The submarines *Porpoise, Seahorse* and *Starfish* of the 1930 Program will be completed during 1933. The *Porpoise* (Messrs. Vickers-Armstrongs, Ltd.) will join the Fifth Submarine Flotilla at Portsmouth, and the *Seahorse* and *Starfish* (Chatham Dockyard) will relieve submarines of the *H* class in the Sixth Submarine Flotilla at Portland.

The sloops *Milford* and *Weston* (Devonport Dockyard, with propelling machinery by Messrs. Yarrow & Co., Ltd.), and *Dundee* (Chatham Dockyard, with machinery by Messrs. R. and W. Hawthorn, Leslie & Co., Ltd.), of the 1930 Program, have replaced, or will shortly replace, old sloops abroad. The *Falmouth* (Devonport Dockyard, with machinery by Messrs. R. & W. Hawthorn, Leslie & Co., Ltd.) has replaced the *Petersfield* as tender to the flagship on the China Station. The *Guardian*, a sloop fitted for netlaying and for target-towing (Chatham Dockyard, with machinery by the Wallsend Slipway and Engineering Co., Ltd.), will be completed about the end of June, 1933, and will in due course replace the *Snapdragon*.

The gunboat *Sandpiper* (Messrs. John I. Thornycroft and Co., Ltd.), of the 1931 Program, will be completed at Shanghai in June, 1933, for service on the Yangtse. This vessel has been designed specially for service on the lakes during the low-water season.

EXPENDITURE ON DOCKYARD-BUILT SHIPS.

For expenditure on the cruiser *Leander* (Devonport Dockyard, with propelling machinery by Messrs. Vickers-Armstrongs, Ltd.) during the financial year just begun, £35,081 is provided, including £28,041 for contract work in connection with the machinery.

For expenditure on the cruiser *Neptune* (Portsmouth Dockyard, with propelling machinery by the Parsons Marine Steam Turbine Co., Ltd.) during the financial year 1933, £594,469 is provided, including £63,336 for contract work in connection with the machinery. For the cruiser *Orion* (Devonport Dockyard, with machinery by Messrs. Vickers-Armstrongs, Ltd.) the corresponding figures are £569,543 and £81,600; for the *Amphion* (Portsmouth Dockyard, with machinery by Messrs. William Beardmore & Co., Ltd.), £460,929 and £175,000; for the *Arethusa* (Chatham Dockyard, with machinery by the Parsons Marine Steam Turbine Co., Ltd.), £498,692 and £190,500; and for the *Apollo* (Devonport Dockyard, with machinery by Messrs. William Beardmore & Co., Ltd.), £363,060 and £73,000. The *Neptune* and *Orion* are to be completed in the financial year 1933; the *Amphion* and *Arethusa* in 1935, and the completion date for the *Apollo* is not stated.

The sum provided for expenditure during the financial year 1933 on the flotilla-leader *Duncan* (Portsmouth Dockyard, with propelling machinery by Messrs. William Beardmore & Co., Ltd.) is £14,159, including £13,382 for contract work in connection with the machinery; while for the flotilla-leader *Exmouth* (Portsmouth Dockyard, with machinery by the Fairfield Shipbuilding & Engineering Co., Ltd.) the corresponding sums are £163,398 and £98,000. The *Exmouth* is to be completed in 1934.

For expenditure on the submarines *Starfish* and *Seahorse*, £162,869 is provided; on the submarine *Shark*, £131,463; and on the submarine *Grampus*, £101,441. All these four vessels are being built at Chatham Dockyard. The *Starfish* and *Seahorse* are to be completed in the financial year 1933, the *Shark* in 1934, and the date for the completion of the *Grampus* is not stated.

For the sloops *Grimsby* and *Leith* (Devonport Dockyard, with propelling machinery by Messrs. J. Samuel White & Co., Ltd.), £202,603 is allocated, including £34,400 for contract work in connection with the machinery; and for the sloops *Lowestoft* and *Wellington* (Devonport Dockyard, the machinery not yet ordered), £111,079 is provided, including £32,000 for machinery. The *Grimsby* and *Leith* are to be completed in the financial year 1934.

For the netlayer and target-towing vessel *Guardian* (Chatham Dockyard, with propelling machinery by the Wallsend Slipway and Engineering Co., Ltd.) the sum provided for expenditure during the financial year 1933 is £72,516, including £13,998 for contract work in connection with the machinery. The *Guardian* is due for completion in the financial year just begun.

EXPENDITURE ON CONTRACT-BUILT SHIPS.

On the cruiser *Achilles* (Messrs. Cammell, Laird & Co., Ltd.), £379,767 is estimated to be spent in the financial year 1933, of which £196,430 is for contract work in connection with the hull and £71,632 in connection with the machinery. For the cruiser *Ajax* (Messrs. Vickers-Armstrongs, Ltd.), the corresponding sums are £631,270, £333,550 and £177,500; for the cruiser *Phaeton* (Messrs. Swan, Hunter & Wigham Richardson, Ltd., with propelling machinery by the Wallsend Slipway & Engineering Co., Ltd.), £403,653, £218,000 and £70,500; and for the cruiser *Galatea* (Scotts' Shipbuilding & Engineering Co., Ltd.), £329,785, £174,000 and £65,500. The *Achilles* is due for completion during the financial year 1933, the *Ajax* in

1935, and the dates for the completion of the *Phaeton* and *Galatea* are not stated.

For the destroyer-flotilla leader *Faulknor* (Messrs. Yarrow and Co., Ltd.), the total expenditure during the financial year 1933 is estimated at £80,170, of which £33,000 is for contract work in connection with the hull and £40,040 for the machinery.

The total amounts allocated for expenditure during the year on the eight destroyers ordered under the 1931 Program are as follows:—*Echo* and *Eclipse* (Messrs. William Denny and Brothers, Ltd.), £340,246; *Electra* and *Encounter* (Messrs. R. and W. Hawthorn, Leslie & Co., Ltd.), £340,306; *Escapade* and *Escort* (Scotts' Shipbuilding & Engineering Co., Ltd.), £340,272; and *Esk* and *Express* (Messrs. Swan, Hunter & Wigham Richardson, Ltd., with propelling machinery by the Wallsend Slipway and Engineering Co., Ltd.), £341,301, including £138,500 for contract work in connection with the hull and £178,020 for the machinery. These eight destroyers are all due for completion during the financial year 1934. The amounts provided for expenditure on the eight destroyers of the 1932 Program are as follows:—*Fearless* and *Foresight* (Messrs. Cammell, Laird and Co., Ltd.), £146,089; *Foxhound* and *Fortune* (Messrs. John Brown & Co., Ltd.), £146,089; *Forester* and *Fury* (Messrs. J. Samuel White & Co., Ltd.), £146,084; and *Fame* and *Firedrake* (machinery by the Parsons Marine Steam Turbine Co., Ltd., and hulls by Messrs. Vickers-Armstrongs, Ltd.), £146,084, including £62,000 for contract work in connection with the hulls and £70,020 for the machinery.

The sums set aside for expenditure during the financial year just begun on contract-built submarines are as follows:—*Porpoise* (Messrs. Vickers-Armstrongs, Ltd.), £20,788; *Severn* (Messrs. Vickers-Armstrongs, Ltd.), £280,980; *Clyde* (Messrs. Vickers-Armstrongs, Ltd.), £93,569; *Sealion* (Messrs. Cammell, Laird & Co., Ltd.), £128,481; and *Salmon* (Messrs. Cammell, Laird & Co., Ltd.), £34,300.

The sum provided for expenditure in 1933 on the destroyer-depot ship *Woolwich*, which has just been ordered from the Fairfield Shipbuilding & Engineering Co., Ltd., is £120,066.

The following sums have been allocated for expenditure during the financial year 1933 on sloops under construction in private yards:—*Halcyon* and *Skipjack* (Messrs. John Brown and Co., Ltd.), £176,652; and *Harrier* and *Hussar* (Messrs. John I. Thornycroft & Co., Ltd.), £85,701.

The construction of the gunboat *Sandpiper* (Messrs. John I. Thornycroft & Co., Ltd.) will require £17,353 during the financial year just begun; the gunboat *Robin* (Messrs. Yarrow and Co., Ltd.), £56,031; the boom-defense vessel *Aldgate* (not yet ordered), £24,056; the *Elfin*, tender for submarine depot, Portland (not yet ordered), £17,864; and the *Redwing*, tender for torpedo school, Devonport (not yet ordered), £17,708. All these five vessels are to be completed during the financial year 1933.

TECHNICAL PROGRESS.

All submarines have now been equipped with Davis submerged escape apparatus, which provides the crew of a disabled submarine with their own means of escape, entirely independent of special lifting or salvage appliances. Special escape hatches and indicator buoys have been, or will be, fitted to all submarines to facilitate the escape and rescue of the escaping crews. This method of escape, which entails the flooding of the disabled submarine, has been accepted by the Admiralty, in preference to the many ingenious devices for raising sunken submarines which have been considered.

Owing to the salvage operations on H.M. submarine *M 2* (abandoned on the 9th December, 1932), it was not possible to carry out the confirmatory deep diving trials foreshadowed in the statement accompanying the 1932 Estimates. It is, however, hoped that these will be carried out in 1933.

The new model-experiment tank at Haslar for testing ship models has now been completed and brought into use.

Trials of a boiler of a new express type have been satisfactorily carried out, and will be continued under service conditions in H.M.S. *Guardian.*

Arrangements have also been made to carry out trials of another type of water-tube boiler in course of manufacture, which offers the possibility of a greater output for a given weight. It will be fitted in one of H.M. ships for trial under service conditions, subject to satisfactory shop tests.

Experimental work on standard-type boilers of increased size has been carried out, and the information obtained has led to the development of larger boiler units in new designs, with an attendant saving in machinery weight.

Trials of various fuels, including burning tests of coal-oil mixtures and of fuel oil produced from coal, have been continued at the Oil-fuel Experiment Station, Haslar.

After preliminary trials in H.M.S. *Winchester,* a contract has recently been placed (as already announced in this journal) for a quantity of oil fuel produced from British coal by low-temperature carbonization, and this is being tried in a number of H.M. ships.

Steady progress has been made at the Admiralty Engineering Laboratory in the development of high-speed ignition-compression oil engines for naval purposes.

The development of high-speed heavy-oil engines of relatively low power, suitable for generators and boat work, is being closely watched; and a number of tests have been carried out with commercial engines, which show promise of suitability for naval requirements, in order to widen the field from which such engines can be obtained. The use of such designs afloat is being extended rapidly for electrical generators in new cruisers and destroyers, and also for use as propelling units in ships' power boats.

Progress has been maintained in increasing the facilities for self-maintenance in existing vessels, and the amenities in the smaller vessels of the Fleet have been improved by the provision of small automatic refrigerating plants.

Economy has been effected by adopting a simplified system of fire control in some of the new ships and also by reducing complication in gun mountings. —"The Shipbuilder and Marine Engine-Builder," April, 1933.

ENGINE COOLING RESEARCH.*

By R. McKinnon Wood.

The air-cooled aircraft of the past, with its bare cylinder heads, is an abomination to the aerodynamically minded. Its speed falls far short of that of the aeroplane with the water-cooled engine, at speeds of the order of 200 miles an hour. It is not possible to estimate exactly the fraction of the developed horsepower which is spent in cooling by exposed cylinders, but the figure appears to be about one-third at a speed of 180 miles an hour. The comparable figure for a water-cooled engine with a retractable radiator seems to be about one-eighth. These figures are in respect of drag alone;

* Abstract of paper read before the Royal Aeronautical Society, March 9th.

the weight involved in cooling has not been taken into account. The water-cooled installation is heavier, but this greater weight is roughly counterbalanced by the greater supply of fuel demanded by the air-cooled engine.

Some time ago the writer made an estimate of the power which must necessarily be expended in air-cooling, and reached the conclusion that it was very much less than that spent in the best installations in use, either air-cooled or water-cooled, excepting only such aircraft as the Schneider Trophy racers—in which the heat is transferred through the surface of wings, body and floats. The estimate represented an ideal which would never be reached in practice, but one to which approximation should be possible. It assumed streamline motion throughout.

The conception of the air-cooled engine of the future was on the following lines. The cross-section area would be reduced until the engine would conveniently fit into a body of good form and of the maximum sectional area demanded by the purpose of the aircraft. Reduction gearing would assist this decrease of cross section, for the large diameter of existing radial engines is related to the use of a direct drive. A lengthening of the airscrew shaft might also help in adapting the engine to the streamline. The cylinders would be generally of existing form, but, speaking from a purely aerodynamic standpoint, "side" valves behind the cylinders should aid greatly in carrying through the conception to the best result by leaving the cylinders with clean heads for cooling purposes. The cylinders would be given the maximum practicable area of fins and enclosed in sheet metal jackets through which the cooling air would flow, thus avoiding the waste effort of carrying surplus air through the body of the aircraft. The ducts would be carefully shaped from entrance to exit to minimize loss of energy by avoiding sharp curves and rapid expansions. The circulation would be partly or wholly produced by an airscrew fan driven by the engine through gearing, revolving considerably faster than the airscrew—at between 3000 and 4000 R.P.M.

It will be seen that there are two separable ideas here. First, the jacketed engine with carefuly streamlined passages; secondly, the introduction of the fan, and the latter can again be separated into the introduction of the fan as an auxiliary and the use of the fan to give the sole motive force. The first idea is not new in aeronautics. The second idea is about as old as the motor car; but a little more thought must be put into the aero-engine fan. The fan may conceivably meet four needs. First, airscrews can be highly efficient and, although it may seem that flight-induced flow is a gift, it is not clear from first principles that flight flow through a body does not entail a large expenditure of energy in relation to the work done in overcoming the resistance in the passage. The relative merit of fan flow and flight flow probably depends upon the amount of flow required, the former being better for larger flows. The writer was inclined to the opinion that the fan would be distinctly more efficient for the quantity of flow required to cool an engine. Secondly, we are close to the limit of the cooling we can supply in existing cowled installations. The fan may extend this limit almost indefinitely. Thirdly, the fan gives a means of adjusting the cooling, should it be inadequate or excessive in a specific case, and one which is more easy and more potent than the rearrangement of cowling. Fourthly, the fan offers an automatic regulation of the cooling to suit the flight speed. The larger power expended in cooling air-cooled engines in fast aircraft is largely due to excessive over-cooling at top speed. Water-cooled installations are fitted with shuttered or retractable radiators, primarily, perhaps, to avoid the danger of the water freezing, but, at least incidentally, having an appreciable effect on top speed. The result is far from perfect. The retractable radiator is

the best form in common use, and the power spent in cooling at a top speed of 180 M.P.H. is about three times that spent on climb at 90 M.P.H., the radiator being retracted to give the requisite cooling. Ideally the power should be the same. Perfect regulation and constancy of power spent should be obtained in an air-cooled system in which the circulation is entirely due to the fan.

From the above reasoning it would appear that the fan should provide the whole motive force. This should give perfect regulation and, assuming that fan flow costs less than flight flow, this system should be more efficient on climb as well as at top speed.

The ideas discussed have shown a prospect of marked improvement of the air-cooled aeroplane based on a number of very debatable points which call for experiment. Preliminary experiments have been made at the R.A.E. by Mr. Hartshorn.

The first series of experiments were made with a finned steel cylinder, about 6 inches in diameter and 6 inches long, enclosed in a duct built of wood. The duct started with a rounded entry, divided symmetrically round the cylinder and rejoined, and terminated after expanding in a large box. In the box the air first passed a large area of gauze and then through two sharp-edged orifices into a second large chamber, from which it was exhausted by a centrifugal blower. From the pressure in the first and second compartments, the flow of air and the loss of energy could be found. The cylinder walls were heated by steam from an electrically heated boiler below the radiator. The electrical input was adjusted to keep the pressure in the cylinder constant and approximately atmospheric. By this arrangement, the walls were kept at a uniform known temperature, and the heat flow was measured by the electrical input required. It was found that the power expended in cooling varies rapidly with cooling speed—roughly as the cube. The heat flow varies slowly with the speed; in fact, it increases about 50 per cent when the speed is doubled from 50 feet to 100 feet per second, and doubles when the speed is trebled. This is due to two causes. First, the heat flow with a given difference of temperature between surface and air varies less than in proportion to the speed; secondly, there is a considerable drop of temperature along the fins and this drop increases as the heat flow is increased by raising the speed. The metallic resistance to the heat flow from cylinder to cooling surface is an important factor. It is evident that the use of a metal with a higher conductivity than steel, *e.g.*, aluminum or copper, would have a big influence on the economy of cooling. It is also clear that the maximum possible cooling surface should be provided. The two *desiderata* are likely to be in conflict, since steel can be worked thinner than aluminum. It should, however, be noted in this connection that there is a limit to the closeness with which fins can effectively be spaced, as has been shown by recent experiments in the United States of America. The heat extracted by the air falls off rapidly when the surfaces are brought too close together, and Mr. Pye has related this phenomenon to the mingling of the boundary layers.

Passing to the second series of experiments designed to investigate the second idea, the introduction of the fan, it was decided to idealize the model to the simplest form which would include the essential features of the problem, but recognizing that there were certain overall dimensions which must be quantitatively to scale. For the first stage, which is now completed, the airscrew was omitted. The body used was a solid of revolution. The cylinders were represented by a ring of gauze. The area of this ring, and the resistance of the gauze were designed to represent the section area and resistance of the passages through an engine designd in accord with the general conception. An eight-bladed fan was designed to impart the required

power with fair efficiency, the blades moving in an annulus the same dimensions as that of the gauze. The fan was driven by a small A.C. motor housed in the body, and provision was made to measure the torque and the revolutions. Small pitot tubes and static pressure holes were inserted to obtain the speed of flow, the thrust of the fan, and the resistance of the gauze. The annular air passage was parallel from ahead of the fan to some distance behind the gauze, and generally parallel from the entrance. The annulus enlarged to the exit, a little ahead of the maximum section of the body.

To sum up the results of this second series of experiments, it has not been proved that fan induction is more efficient than flight induction for the rate of flow required. On the other hand, a strong case can be made for the fan as a means of giving more cooling if flight induction fail; as an easy means of adjusting the cooling; and, most important, as providing a large measure of automatic regulation with flight speed which has an important influence on the top speed.

The work done in forcing the air over the cooling surfaces, even in the idealized model of the experiments, is much greater than the ideal skin friction loss, and here, in particular, further study is required and the problem needs to be studied in closer relation to the practical details of engine design. In addition it is important to inquire into every possible means of reducing the speed of flow required for cooling, since the power consumed varies roughly as the cube of the speed.—" The Engineer," March 17, 1933.

ASSOCIATION NOTES.

The Society has sustained very great loss in the recent death of its President, Rear Admiral William A. Moffett, and of two of its Past Presidents, Rear Admiral Harold P. Norton, Retired, and Rear Admiral Robert Stanislaus Griffin, Retired. It will be difficult indeed for us to fill their places in our ranks. Elsewhere in this number will be found appreciations, which attempt to set forth the exceptional personal and professional qualities of these distinguished officers.

To fill the unexpired term of President of the Society, the Council has appointed Rear Admiral Ernest J. King, Chief of the Bureau of Aeronautics, Navy Department. We feel that we are most fortunate that Admiral King is able to accept this appointment.

The following members have joined the Society since the publication of the last previous JOURNAL:

NAVAL.

Briggs, C. W., Lieutenant, U. S. N. R.

CIVIL.

Fendrich, William, 530 Upper Mountain Avenue, Upper Montclair, N. J.

Haller, L. G., Hedges Walsh Weidner Co., Chattanooga, Tenn.

Quinn, Thomas S., Lebanon Steel Foundry, Lebanon, Pa.

ASSOCIATE.

Bonney, John L. V., Bonney-Floyd Co., Columbus, Ohio.

Guthrie, William J., Denny & Bros., Ltd., Dumbarton, Scotland.

Tyson, John D., Standard Steel Works Co., Burnham, Pa.